HOUSE OF COMMONS

Fourth Report from the

ENVIRONMENT COMMITTEE

Session 1983–84

ACID RAIN

Volume I

Report together with the Proceedings of the Committee relating to the Report

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Ordered by The House of Commons *to be printed*
30th July 1984

LONDON
HER MAJESTY'S STATIONERY OFFICE
Reprinted 1985
£5.55 net

446–I

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The Environment Committee is appointed under SO No 99 to examine the expenditure, administration and policy of the Department of Environment and associated public bodies, and similar matters within the responsibilities of the Secretary of State for Northern Ireland.

The committee consists of a maximum of eleven members, of whom the quorum is three.

The committee has the power:—

(*a*) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(*b*) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the committee's order of reference;

(*c*) to communicate to any other such committee its evidence and any other documents relating to matters of common interest; and

(*d*) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

Unless the House otherwise orders, all Members nominated to the committee continue to be members of the committee for the remainder of the Parliament.

FRIDAY 9 DECEMBER 1983

The following were nominated as members of the Committee: Mr Richard Alexander, Mr David Alton, Mr Sydney Chapman, Sir Reginald Eyre, Mr Reginald Freeson, Mr Robert B. Jones, Mr Norman Miscampbell, Mr Allan Roberts, Sir Hugh Rossi, Mr Chris Smith and Mr John Mark Taylor.

Sir Hugh Rossi was elected Chairman 15 December 1983.

FRIDAY 27 JULY 1984

Sir Reginald Eyre discharged; Mr Julian Critchley added.

The cost of printing and publishing this Report is estimated by Her Majesty's Stationery Office at £6,150.

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FOURTH REPORT

ACID RAIN

The Environment Committee has agreed to the following Report:

I. INTRODUCTION

What is acid rain?

1. Acid rain is one of the major environmental hazards faced by the industrialised world today. What it is and what it does are imperfectly understood. As a consequence there exists in our country a reluctance to take action.

2. We commenced our inquiry with open minds. We are now convinced, and by our Report hope to show, that immediate and hard financial decisions have to be taken as time is running out. Simply to plead for more research into cause and effect is but to procrastinate. Enough is now known to justify the development and application of technology for removing the causes of effects now abundantly apparent.

3. The term "Acid Rain" was first used in 1872 to describe the atmospheric chemical processes whereby sulphur dioxide, emitted when coal is burnt, falls as sulphuric acid in rain. Today it is used to describe acid deposition, wet, dry, and occult (ie, mists, fog) caused by a number of pollutants emitted when fossil fuels are burnt. The term is both graphic and evocative, thereby readily lending itself for political purposes.

4. We ran into constant difficulties with witnesses using the term 'acid rain' in different ways. For this Report we use the words in their widest and most inaccurate sense, deliberately so, because they most readily cover the areas which are of major concern: namely, the consequences to water-life, the forests, buildings and human health of the chemical changes in the atmosphere to emissions from combusted fossil fuels. These emissions may be sulphur dioxide (SO_2), nitrogen oxides (NO_x) or hydrocarbons. Their major products are sulphuric and nitric acids (H_2SO_4 and HNO_3), nitrogen dioxide (NO_2) and also ozone (O_3). Hydrocarbons are produced by both motor vehicles and refineries/petrol-chemical works, and play a significant role in the process by which ozone is formed from NO_x. All singly or in combination appear to have effects which give cause for concern. All fall within the sense in which we use the term "Acid Rain".

The UK's contribution to the acid rain problem

5. The Government, in virtually every parliamentary answer to questions seeking controls, and, in response to demands to join the "30 per cent club" (that is, countries committed to a 30 per cent reduction in their SO_2 emissions between 1980 and 1993), has rightly cited the fact that the United Kingdom's emissions of SO_2 have fallen by 37 per cent since 1970, considerably closing the gap between us and other countries. However, in 1970 the United Kingdom was and in 1984 still is the largest producer of SO_2 in Western Europe.

6. The Central Electricity Generating Board (CEGB), despite its being the major burner of fossil fuels in this countrry, has made virtually no reduction in its SO_2 emissions. By following a tall stacks policy the CEGB has lessened the acid deposition falling near to power stations but has caused it to be transported over

long distances; thus, it can be assumed, increasing the amount of depositions falling in rural areas and even in areas as remote as Scandinavia. Many such areas are those more ecologically sensitive where persistent levels of acid rain can have the worst effect (Fig 1).

7. Britain is the principal foreign depositer of SO_2 in Scandinavia. By 1990, the biggest single polluter of Swedish forests and lakes—even if we join the 30 per cent club—will be the United Kingdom. We already deposit 50 per cent more than any other country in Norway. It remains the case that in Western Europe only West Germany exports more SO_2 which is deposited in other countries than the United Kingdom.[1] By implementing the EEC draft directive to reduce SO_2 emissions by 60 per cent between 1980 and 1995,[2] the Government now has an opportunity to reverse this state of affairs, and take as positive a step as it did on lead in petrol.

8. Ozone has emerged as one of the primary suspects of tree damage observed in German forests. This fact has been cited by the CEGB and motor manufacturers as a reason for not controlling their NO_x emissions. We are unsure whether this was the product of ignorance or a deliberate attempt to mislead us. Ozone pollution is the consequence of NO_x and hydrocarbons. NO_x emissions in this country are largely from the CEGB (55 per cent), and motor cars are major emitters of both NO_x and hydrocarbons. No significant steps have yet been taken to control NO_x and no reductions of significance in NO_x emissions have been recorded in the United Kingdom. The EEC draft directive requires a reduction in NO_x emissions of 40 per cent by 1995.

On what do we base a decision?

9. Many scientists freely admit that they do not fully understand the complex chemical processes by which the ultimate products of fossil fuel emissions cause damage. Most admit that there is a connection, with some links missing. A dominant feature of the debate on acid rain has been the demand by some interests in this country for the proof of the existence of a complete causal chain between emitted pollutants, their derivatives and the observed damage caused. The lack of the complete chain has been used as the best reason for not taking action, but for instituting further research. This demand, however, is not so pronounced in the worst affected countries, Scandinavia and West Germany. On our visits to those countries scientists there indeed confessed to us that various processes involved in acidification are imperfectly understood, but they were certain that emissions do have serious adverse effects.

10. Another factor which has militated against decisions being taken to prevent acid rain in the United Kingdom is the relative lack of public awareness of the problem. In West Germany there is widespread concern over forest damage, in Scandinavia over fish-kills in rivers and lakes, all on an extensive scale. Our work has shown that environments similar to those effected in Scandinavia exist in parts of the United Kingdom, but so far only very limited damage has been observed. The Forestry Commission was sceptical, in the absence of extensive damage, of the existence of significant risks from acid rain. The CEGB set four criteria for

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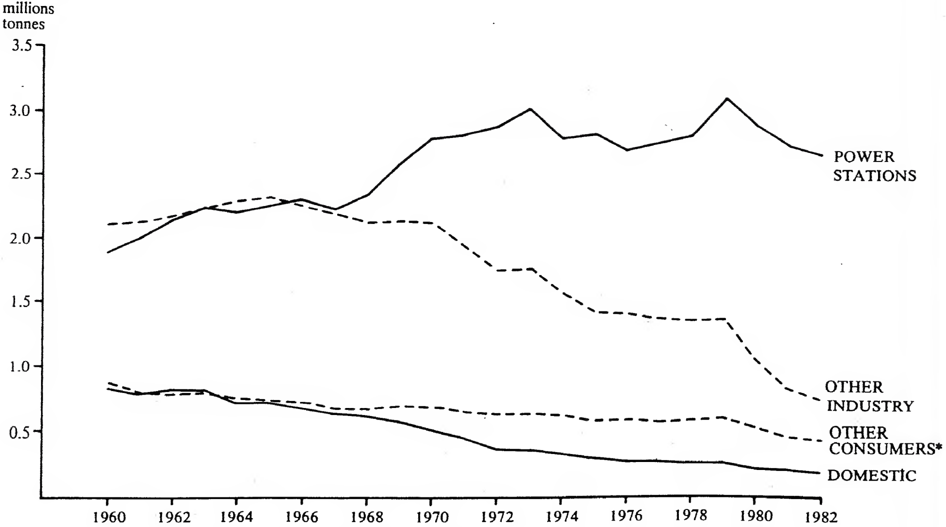
[1] Ev, p 64

[2] Com (83) 704

FIGURE 1
UK SULPHUR DIOXIDE EMISSIONS BY SOURCE



* *including road and rail transport, refineries and commercial/public service*

moving to controls, including observed damage.[3] They completely ignored the "insurance" element. However, the Nature Conservancy Council has shown the extent of the risk.[4]

11. We were very impressed by the views presented to us through the NERC by scientists independent of any manufacturing or industrial interests. They told us that scientific work had advanced far enough for a decision to be taken. Like lead in petrol, it had become "a matter of public political will, something will have to be done". They told us "there is sufficient evidence on which action should be taken—various forms of action."[5] A similar view was put to us by scientists abroad, and in particular by Dr Oden, the Swedish scientist who first drew attention to the problems of acid rain in its present form. The German Government has been through exactly that process, and their Minister, Herr Spranger, testified to us as to the depth of public support and the adequacy of scientific data. The European Commission believe a decision can now be taken.[6]

12. In our Report we set out what, in our view, are the facts and risks which should form the background to such a policy decision. We examine various types of damage attributed to acid rain—buildings, freshwater systems, fish, trees, crops, other plants, materials, visibility and human health. The Minister responsible for these matters at the Department of the Environment, Mr William Waldegrave, said electricity consumers needed to be given a reasonably convincing picture of the environmental benefits that would result from emission controls putting up production costs.[7] In each area of damage we therefore assess the effects atributed to acid rain and whether those effects could be reduced or reversed by reduced depositions. We then set out the sources of the pollution, both countries and, for the United Kingdom, types of emitters. We then consider the control technology available to reduce those emissions, its costs, and how those costs should be assessed against environmental damage or risk of damage in order to reach a conclusion on the desirability of controls. Our conclusions follow.

13. Our work is based on extensive written evidence from scientists, Government departments, private companies and nationalised industries. We received oral evidence from the Central Electricity Generating Board, Friends of the Earth, the Department of the Environment (both the Minister, Mr Waldegrave, and officials), Warren Springs Laboratory, Society of Motor Manufacturers and Traders, the Confederation of British Industry (CBI), the Natural Environment Research Council (NERC), the Forestry Commission and the National Coal Board. We visited West Germany, Sweden, Norway, Scotland, the Lake District and the Central Electricity Research Laboratory at Leatherhead. During our visits we held discussions with Ministers, civil servants, scientists, farmers, and others, and saw at first hand environmental damage attributed to acid rain. We draw heavily on our findings from these visits throughout our Report. During our inquiry we benefited considerably from the specialist advice given to us by Professor Alan Williams of the University of Leeds and Dr Nigel Bell, of Imperial College London. We take this opportunity to thank all who have assisted us during our work.

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[3] Ev, p 1
[4] Acid Deposition and its implications for nature conservation in Britain, Nature Conservancy Council, 1984 (NCC 1984).
[5] Q590
[6] AR 63
[7] Q657

II. ENVIRONMENTAL IMPACT OF ACID RAIN

14. We begin, therefore, by examining the effects acid rain is said to have on the environment: on buildings, aquatic freshwater life, plants, materials, visibility and human health. We seek to show the different ways in which acid rain causes damage. We draw attention to factors other than acid rain which are relevant to the environmental damage attributed to acid rain. Throughout, we attempt to answer two crucial questions: is the damage observed the consequence of the emissions of fossil fuels? Is the evidence sufficiently strong for each category of damage to show that a reduction in acid rain deposition would reduce or reverse the damage?

A *Damage to buildings*

(a) How acid rain damages buildings

15. The damage of stone by SO_2 and its compounds in particular, as well as by NO_x, is a long-standing environmental problem.[8] The Stone Federation gave evidence that limestones, marble, some sandstones and certain types of slate used in this country "are directly affected by sulphur dioxide and show the effects to a greater or lesser degree."[9] It affects both historic and modern buildings. Types of limestone are particularly vulnerable. They are also the main types of building stones used in most of this country's great medieval and later architectural monuments.

16. How that damage occurs is generally well-understood. Acidic rainwater may dissolve stonework. The CEGB dismissed this: to dissolve an inch of limestone would take 5,000-20,000 years.[10] However, there is no doubt, according to the Buildings Research Establishment and the Historic Buildings and Ancient Monuments Commission, that more acidity leads to more decay.[11] The two mechanisms of damage ignored by the CEGB in telling us that sulphur emissions or acid rain had minimal effect[12] are as follows. First, a combination of dry deposition of SO_2 followed by rainfall leads to the production of calcium sulphate within a stone (usually limestone) which then causes the surface to break off.[13] This we observed at first hand at Cologne Cathedral. Second, a hard, blackened surface skin forms on stone which ultimately blisters, disfiguring surfaces and carvings. Some German evidence points to a further effect in some types of concrete.[14] SO_2 seeps through to reinforcements and causes oxidation (rust). Internal volume increases, causing pressure and damage to concrete from within, as well as weakening the metal reinforcement. The role of dry deposition was ignored by the CEGB in their evidence to us, but is critical. These effects are a consequence of SO_2 in the atmosphere, and therefore of "acid rain" in its most broadly understood sense.

(b) *Research on the mechanisms of damage*

17. Given the importance of this type of damage, surprisingly little research has been done, although such work as we have been able to consult points to the

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[8] Ev, p 69
[9] AR 88
[10] Q48
[11] Q237 and AR 71
[12] Q39
[13] Q230
[14] See also AR 98

significance of SO_2 pollution and to a direct relationship between exposure to SO_2 and weight loss. The Building Research Establishment (BRE) demonstrated some twenty years ago that Portland stone exposed at Westminster eroded 250 per cent more than similar stone at a rural location where the SO_2 content of the air was between ⅕ and 1/12 of that at Westminster.[15] Given that 80 per cent of SO_2 in the atmosphere in North West Europe is man-made, it is reasonable to assume that air pollution accelerates weathering. Therefore a reduction of SO_2 depositions would reduce the rate of weathering. Given also that dry deposition is more local than wet, this points to a direct benefit to the United Kingdom in reducing emissions. West German research has recently confirmed this (fig 2).

18. We consider the absence of serious research commissioned of the BRE has been a major failure. It seems to have been presumed that when the Clean Air Act removed most visible pollution, the need for research on the effects of air pollutants on buildings ended. The result has been that Ministers do not have the quality of research available to them in reaching conclusions on damage to buildings that they could reasonably expect. Whilst all available evidence points to serious damage, there are few research results available to establish a "dose-effect" relationship, that is, between the amount of acid deposited and the degree of damage suffered. Given that SO_2 pollution has been a subject of international political interest for fifteen years, this shortcoming is to be deplored. **We recommend that BRE be commissioned to conduct detailed research into the effects of acid rain on different types of stone and concrete in a variety of environments.**

19. The CEGB were unable to give us much evidence on buildings, despite their statutory obligation to have due regard for the environment. The effects of high SO_2 levels on buildings (as evidenced even now in Cracow) is well known. Yet no work at all had been done on stone erosion until two years ago and nothing at all on the effects of SO_2 on building materials. We were asked by CEGB to accept that because natural levels of acidity in rainfall had created the Cheddar Gorge and the Kentucky Caves, natural levels should be assessed before any conclusions were drawn about the effects of acid rain on buildings. This evidence seemed trite and evasive. Despite questioning, we received no clear or satisfactory answer as to why their research on buildings had only begun two years ago.[16]

(c) *Is there damage from man-made emissions?*

20. Having established the mechanisms of damage, we turn to a pertinent question put to us by Dr Everett of the BRE: are modern levels of damage above those that would occur if there were no man-made emissions of SO_2?[17] The overwhelming weight of evidence we received was affirmative. We begin by looking at damage in West Germany of which we were told during our visit, and which is similar to damage observed elsewhere in Europe. We then consider evidence of damage in this country.

(i) *West Germany*

21. Considerable concern was expressed to us in West Germany. Damage from SO_2 has been observed on all types of structures and buildings, as well as on bronze and stained glass. It was feared that the staining of some old glass windows

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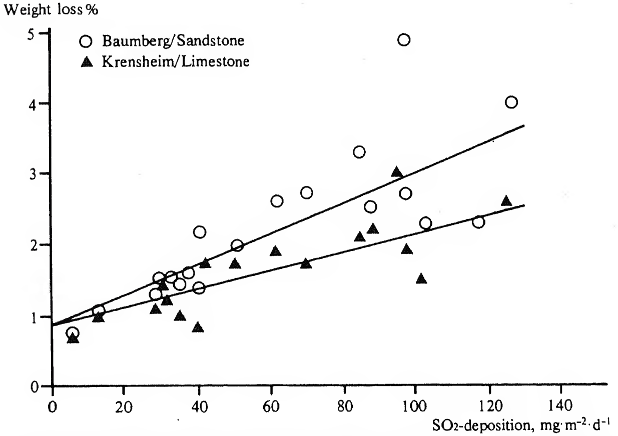
[15] Ev, pp 83–4
[16] Q41-6
[17] Q227

FIGURE 2

Relationship between SO2 content of the atmosphere and effect on sandstone and limestone



The readings were obtained using the IRMA apparatus and the specimens consisted of 60 x 60 x approx. 3 mm plates of Baumberg sandstone and Krensheim limestone.

would disappear within 20 years. Serious losses had occurred on historic monuments. Renovation of the stonework of historic buildings in West Germany costs about £80 million in a year. The total cost of stone repair is put by official sources at over £1,000 million per annum. Other research has suggested extensive damage to concrete in most major German cities, and this is attributed to acid deposition.[18]

22. At Cologne Cathedral we saw 15th century sandstone was being replaced on the walls of the choir alongside 19th century work. Basalt used to build the nave and towers in the 19th century was less affected. Within five years, we were told, none of the original stonework will remain. The Cathedral architect blamed the development of calcium sulphate, due to SO_2 emissions from power stations within 50km. He expressed deep regret that although £1½ million was being spent each year to replace damage stone, what he was overseeing was the replacement of a medieval monument. The result was a copy.

(ii) *The likelihood of damage in this country*

23. Having seen the damage to Colgne Cathedral, and bearing in mind the emphasis given to damage to buildings in cost-benefit analysis by OECD and the

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[18] FRG Munich Multilateral Conference Paper

European Commission, we sought similar evidence here. We were appalled at the lack of monitoring. PSA, the largest manager of buildings in the country, had done no monitoring at all.[19] CEGB had begun work only two years ago. The BRE had done little monitoring since the Clean Air Act. Scientific study was being undertaken by a small group of researchers from University College, London.[20] PSA's Chief Executive accepts that their lack of information did not mean that no cases of damage had occurred. Most defects would have been remedied by local staff without reference to the central Building Advisory Branch. We welcome the undertaking he gave us to carry out a short survey amongst Regional Directors, and **we recommend that suitable cases should as a matter of course be referred to BRE. We also recommend that a selection of buildings in different materials be used by PSA to monitor any damage additional to natural weathering.**

24. In the absence of any collated evidence from those we felt should be able to provide it, we made separate inquiries of the custodians of some of our major and, in theory, most vulnerable monuments; namely, our cathedrals and other historic buildings. As the rate of SO_2 deposition in this country, particularly in urban areas, is similar to that of West Germany, we expected to find, following our experiences there, symptoms of SO_2 damage to our own architectural heritage. The Cathedrals Advisory Committee told us we could expect to find "the most serious effects are those on stone buildings and on stained glass."[21] As the following paragraphs show, we received deeply disturbing evidence concerning some of our greatest buildings: damage to stained glass and sculptures, and decaying stonework. To quote the Department of Energy report, "the cultural value . . . cannot be expressed in economic terms".[22]

(iii) *Some Buildings in the United Kingdom damaged by acid rain*

(a) *Westminster Abbey*

25. Extensive restoration work is underway at the Abbey. It had suffered principally from chemical changes in its limestone from calcium carbonate to calcium sulphate. The Surveyor of the Fabric told us the Abbey "had abundant evidence of stones which are unstable under this attack . . . which I am now replacing at such immense cost . . . Sulphur dioxide and possibly other pollutant gases are the main reasons that this expensive restoration has become necessary." Over the last ten years £5 million has been spent on the restoration of stonework. Forty-four flying buttresses of the south face, which had been rebuilt in limestone only ninety years ago, now require replacement because of SO_2 attack. Although reductions in SO_2 levels will have had a beneficial effect, they remain sufficiently high to continue to accelerate erosion "significantly".[23]

(b) *Lincoln Cathedral*[24]

26. The architects to the cathedral advised us that although no quantifiable evidence could be given because of lack of monitoring, "the recent acceleration in the deterioration of the stonework, particularly that of the Romanesque and medieval statuary, is due to acid rain". The cathedral stands in a position to be exposed to pollutants from the Midlands. It is also in the plume path of Trentside

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[19] Evidence not printed

[20] AR 46

[21] AR 82

[22] Acidity in the Environment, Energy Technology Support Unit, p97 (hereafter cited as ETSU)

[23] AR46

[24] AR 83

power stations. Despite this and the knowledge of CEGB research staff that the cathedral was suffering from SO_2 effects, the CEGB has made no effort to monitor those effects.[25] The photographs show the extent of deterioration in the last 70 years of statuary which had previously survived relatively unaffected by weathering for several hundred years.

(c) *York Minster*[26]

27. The Surveyor to the Fabric reported that extensive damage through the effect of acid rain could be observed on all the external surfaces of the building. The stone of which the Minster is built is principally magnesian limestone, which the BRE told us was particularly vulnerable.[27] Other causes were acknowledged (wind, frost), but nevertheless the Surveyor concluded "there is no doubt that the breaking down because of hard sulphate skin is the prime cause" of stone decay in the Minster. Concern was also expressed at damage to stained glass.

(d) *Beverley Minster*[28]

28. The Minster is built of a very fine grained magnesian limestone, like York Minster and many other buildings, and is therefore "even more reactive than the more usual calcium carbonate limestone". The role of industrial air pollution is demonstrated by the fact that decay is indiscriminately affecting stones of the 13th, 18th and 19th centuries. This confirms that the damaging pollution is relatively recent in the whole life of the building. That trend is evident elsewhere, such as at Chichester Cathedral, where Scott's restoration of the Central Tower and Spire after 1861 is failing due to air pollution.[29]

(e) *Brompton Oratory*[30]

29. This, like St Paul's Cathedral, is built of perhaps the most durable native limestone, Portland. Despite the relative youth of the Oratory, evidence of damage from SO^2 exists in the presence of hard calcium sulphate skin which has split to expose decayed stone within. This is exactly the phenomenon we observed at Cologne Cathedral. It is worst at those points which are exposed to rainfall and go through cycles of dry deposition and rain washing.

(f) *Liverpool Cathedral*[31]

30. Evidence showed the direct role of acid rain in causing the deterioration of the copper covering the roof of the Anglican cathedral. It is worst at those points where water is retained for some time after the main areas of the roof have dried out. Deterioration is continuing, and complete replacement of the copper sheeting is now considered necessary. Many buildings in this country have similar copper roof coverings.

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[25] Q47-8
[26] AR 79
[27] Ev, p 83
[28] AR 81
[29] AR 77
[30] AR 81
[31] AR 87

(g) *St Paul's Cathedral*

31. The Cathedral is clad in Portland stone. Substantial restoration work has shown the extent of damage by atmospheric pollution—principally SO_2. Monitoring demonstrates that the accelerated deterioration due to SO_2 continues (fig 3). Weathering of stonework has been as much as 30.75mm since 1717, and recent work has shown that it is greatest in exposed areas.[32]

32. A Report by the BRE, NERC and University of London concluded these rates at St Paul's "give cause for concern. In areas where dry deposits could be washed off by rain, the effect was less than on limestones which were finer grained. Some effect was, nevertheless, observed. Where polluted water could rest and evaporate slowly, masonry was attacked. Carvings where exposed have suffered most severely." The Report emphasised that "mouldings can be repeated where records of originals remain, but unfortunately this does not apply to carvings which are unique. Those surmounting the north, west and southern pediments, the work of Francis Bird (1667-1731), have suffered appreciably." Original works of art are therefore being lost at St Paul's just as they have been at medieval cathedrals.

(h) *The Palace of Westminster*[33]

33. Similar problems to those at Westminster Abbey have been observed at the Houses of Parliament by PSA. Like York and Beverley Minsters, the Palace of Westminster is built of magnesian limestone. It has suffered serious damage from the presence of sulphur acids in rainfall: PSA advised us that "this had caused both surface powdering, blistering and spalling, and also the dramatic and drastic failure of some of the original . . . stone." The formation of black crystallised surfaces, a typical sympton of SO_2 attack, is extensively apparent in the internal courts. Damage to small detail was widespread. The process of damage was first observed in 1861, within a few years of the completion of the building. Despite the Clean Air Act 1956, SO_2 levels in Westminster remain very high, and although the rate of damage may have declined, it is reasonable to assume that the restored stonework will erode at faster than natural weathering rates.

(i) *General*

34. A more general picture was given us by the Senior Sculpture Conservator at the Victoria and Albert Museum.[34] His department has researched stone decay for twenty years. His conclusions did not make encouraging reading. He said that the problem of decay had accelerated dramatically since the turn of the century; that rural as well as urban areas were affected; that no technology existed to preserve any stone sculpture in an external environment. There is, at present, no method of reducing weathering caused by air pollutants except to reduce the SO_2 levels themselves.

(d) *Conclusion: the need for controls to protect our architectural heritage and modern buildings*

35. Evidence shows that even now, after the Clean Air Act and tall stacks policy, weight loss of selected building stones exposed to rainfall is significantly

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[32] Ev, p 84

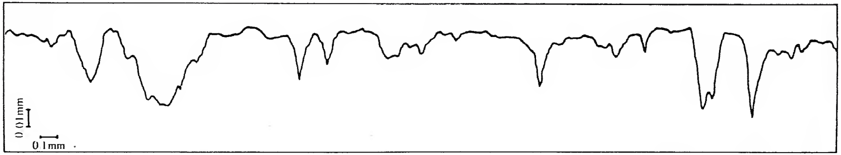
[33] Evidence from PSA, not reported.

[34] AR 80

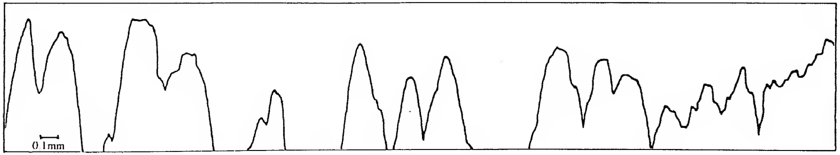
FIGURE 3

Different Rates of Stone Weathering Surface traces of tablets (10x vertical exaggeration)

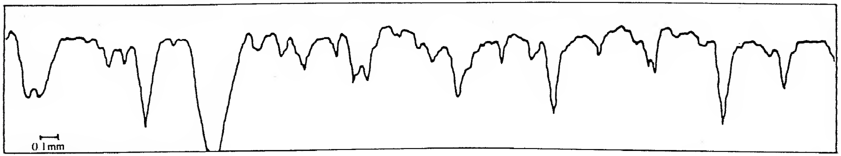
A. Unweathered stone surface



B. Weathered stone surface, exposed to rainwash; exposure at St Pauls Cathedral, City of London



C. Weathered stone surface, protected from rainwash; exposure at St Pauls Cathedral, City of London



Source: Professor R.U. Cooke

higher in central London than rural areas.[35] It also shows that even in rural areas air pollution continues to be damaging. Damage not directly due to acid rain or SO_2 emissions, such as salt crystalline attack, is exacerbated when limestone reacts with acidic materials in the air.[36] Even weakly acidic rainwater dissolves limestone albeit slowly.[37] That damage to buildings constructed in materials other than limestone and sandstone takes place has been demonstrated in West Germany. It is, therefore, beyond doubt that acid rain, mainly due to SO_2 emissions, is damaging British buildings, and slowly but surely dissolving away our historic heritage.

36. BRE is doing research to attempt to quantify a "dose-effect" relationship to assist a cost-benefit analysis.[38] This is entirely to be encouraged for modern buildings. They acknowledge, however, that protection rather than prevention is prohibitively expensive. BRE costed protection at £5 a square metre,[39] and said "there will be many hundreds of thousands of millions of square metres that you would need to protect".[40] Further research is needed to assess the full role of local, low-level emission sources. These are not as tightly controlled in the draft EEC directive as major sources, although ultimately West German controls are to be as stringent for both. Such research might well show that damage to buildings requires the control not only of large but also of small plants. **We recommend that a substantial research programme on the effect on buildings of low-level emissions be initiated.**

37. A research programme, over an inevitably long time-scale, would not meet the concern we encountered at Cologne and from those responsible for the fabrics of some of our great buildings. The architect responsible for Beverley Minster summed this up: "many of our most valuable stone buildings are now suffering from accelerating decay of their most characteristic features. In many cases exquisite and often irreplaceable medieval craftsmanship, which has endured for centuries, is literally disintegrating before our eyes".[41] The Surveyor to the Fabric at St Paul's, who has also worked at Oxford Colleges, told us "nothing can prevent the destruction of carvings and other vulnerable detail in exposed positions from acidic attack short of the elimination of the pollutants which are discharged into the atmosphere, and of these sulphur dioxide is the most destructive."[42] We entirely agree, and find intolerable the destruction of important features of priceless buildings. In addition, we are conscious of the cost of making good the damage caused by SO_2 emissions, and that such damage is less in areas where SO_2 concentrations are lower. The Department of Energy's report concluded that "it is clear that . . . the accelerated destruction of stonework is, economically, very significant".[43] From the evidence on buildings, both cultural and economic arguments point strongly towards the need for the substantial reduction of emissions. The problem is urgent. Immediate action is essential. **We recommend that the Government give urgent and immediate consideration to the cost benefit of preventing the avoidable erosion of both historic and modern buildings.**

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[35] AR 46
[36] AR 71, 1, p3
[37] ibid, 2, p2
[38] Ev, p 84-85
[39] Q232
[40] Q234
[41] AR 81
[42] AR 77
[43] ETSU, p 97

B *Damage to lakes, rivers and freshwater life*

Introduction

38. In considering damage to freshwater life, we base our work on the extensive research undertaken in Scandinavia.[44] We discuss the methods by which lakes and rivers become more acid; the extent of damage from acidification observed in Scandinavia; the causes of that acidification and damage; factors other than rainfall, such as afforestation; whether that damage could be reversed. After drawing conclusions about Scandinavian damage, we consider the United Kingdom separately: has damage occurred; do conditions in any parts of the country predispose those areas to damage; would our own environment be less at risk if emission controls were imposed?

EUROPEAN DAMAGE AND RESEARCH

1 *How SO_2 and NO_x emissions get into lakes, rivers and streams*

39. Rain gets into rivers and lakes in one of two ways. First, it falls directly upon surface water. The acidity of the rainfall and the minerals in it therefore affect the water chemistry. Normally, this accounts for only 5-10 per cent of rain inputs to waterways. The remainder enters through or over soils.[45] During this process it picks up minerals, additional acidity and other substances from any vegetation through which it falls. The chemical composition of such rainfall is therefore altered before it reaches surface waters. The pH scale is the main measure of acidity and alkalinity: pH 7 is neutral, any pH level above 7 is increasingly alkaline, any level below 7 is increasingly acidic. In any consideration of acid rain damage, but particularly freshwater damage, it is essential to remember that the pH scale is logarithmic, not linear. A pH change of one unit is a tenfold increase in acidity if the pH falls, or alkalinity if it rises. The graph (Fig. 4, p xxiv) shows this.

40. In certain circumstances, the ratio of nitrates to sulphates entering lakes may reflect that contained in rainwater. However, the continued deposition of sulphates and nitrates in snow over the winter months creates an acid reservoir. This is released over a very short period when the snow melts resulting in acid surges. Norwegian scientists have demonstrated to us that chemical and physical processes taking place within the snowpack result in a concentration of the acids. The result is that as much as 80 per cent of the pollutants are released in the first 30 per cent of snowmelt. The melt water may therefore be much more acidic than the original precipitation. A great deal of this does not soak into the soil, but runs over the surface of the ground. The graph (Fig. 5, p xxvi) shows clearly that the lower the pH of rainfall, the higher the runoff of sulphates, hydrogen ions (H^+) and aluminium, and the lower that of calcium. These acid peaks and the calcium trough can be lethal to aquatic life and some young, newly-hatched fish (fish fry). The significance of this is that snow melts are crucial to fish-loss.

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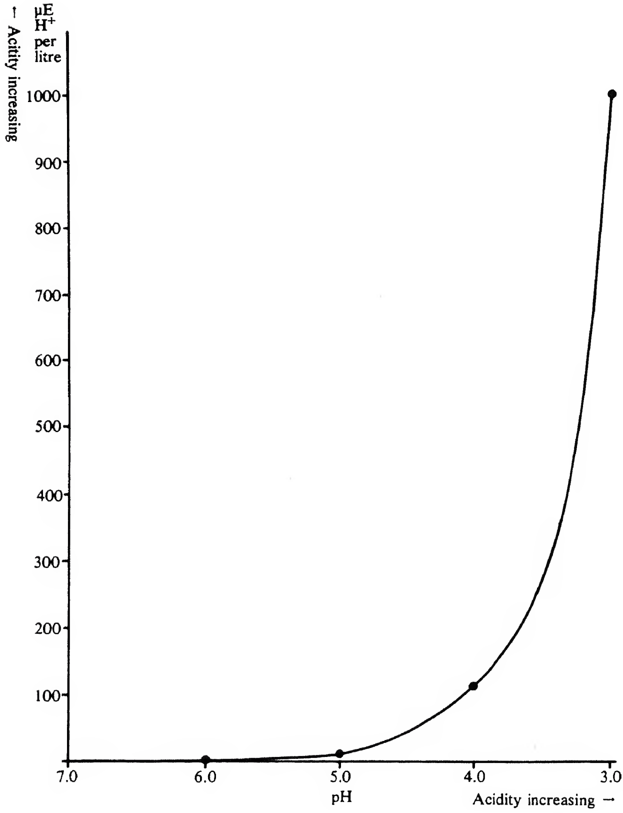
[44] Throughout this section we use Scandinavia to mean Sweden and Norway, the countries we visited and on which we received most evidence.

[45] Q 82

FIGURE 4
The relationship between pH and acidity on a linear scale.



2 *Damage observed in Scandinavia*

41. That there has been a substantial decline in fish populations in southern Scandinavia is undisputed.[46] This decline is argued by Scandinavia scientists to have accelerated in recent years. The CEGB's Director of the Technology, Planning and Research Division argued, however, that this decline had not suddenly accelerated: "the process has been going on for rather longer than people thought".[47] We consider, first, the extent of damage and, second, whether that damage has accelerated in Scandinavia.

(i) *the extent of damage*

42. The Norwegian State Pollution Authority advised us that all lakes in an area covering four counties in southern Norway of 13,000 square km are practically devoid of fish, and in an additional 20,000 square km (7720 sq miles) fish stocks are reduced. A separate survey of 2840 lakes showed 1711 lakes had lost their fish and in 941 fish stocks were declining. Losses are heaviest for brown trout. Atlantic salmon had declined during the 1960's, and monitoring shows that the affected rivers in southern Norway have become more acidic than those further north where salmon are still caught. As in southern Norway, sea trout and salmon catches have fallen. We visited the Tovdal River in Norway, once a major salmon river, where no fish had been caught for over ten years. On this river in the 1930's, two Yorkshiremen caught over a thousand salmon in 39 days using just two rods. In southern Sweden over 18,000 out of a total of 20,000 lakes have been acidified, 4,000 of them seriously enough to damage aquatic life. Work has shown that 1600 populations of roach and 900 of perch have suffered.

(ii) *sudden upsurge.*

43. Fishless lakes undoubtedly existed at the beginning of the century when fish losses began to be observed. However, Professor Lars Walloe,[48] gave us evidence of a dramatic increase in such lakes since 1940. A survey in 1940 showed that of 2500 lakes, 200 had no fish. A resurvey in 1974 showed that the number of fishless lakes had risen to 1500. The graph at p xxvii (Fig. 6) for brown trout losses gives the rate of decline. Many fish catch statistics confirm this. Other surveys for smaller areas have shown a similar rate of decline. This upsurge in the rate of decline of fish life coincides with an increase in European SO_2 and NO_x emissions and with the introduction of tall stacks in power stations in this country and elsewhere causing the long-distance transportation of pollutants. Failure in this country to appreciate the extent of the Scandinavian experience may stem from not distinguishing between acidic lakes and those acidified by pollution. There have always been some lakes too acid to support fish life because of the geology of their water catchment.

44. US evidence shows a similar pattern. In the Adirondack Mountains only 4 per cent of lakes more than 600M above sea level had pH levels of less than 5 per cent in the 1930's. By the 1970's that figure had risen to 51 per cent, most of which had lost their fish. American research has shown that 9,400 lakes and 60,000 miles of streams are currently sensitive to further acid imputs, and that 3,000 lakes and

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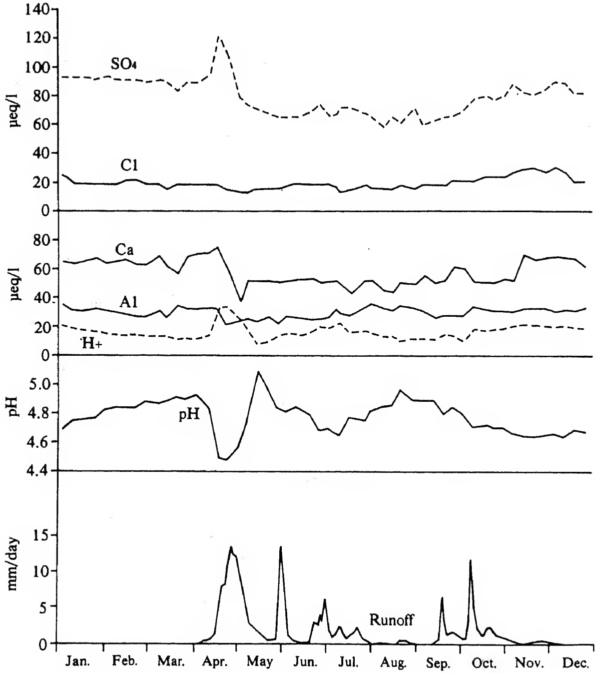
[46] AR 28; AR 12; Q79

[47] Q81

[48] Professor Walloe is a member of the management committee of a Royal Society research project on acid rain funded jointly by the CEGB and NCB.

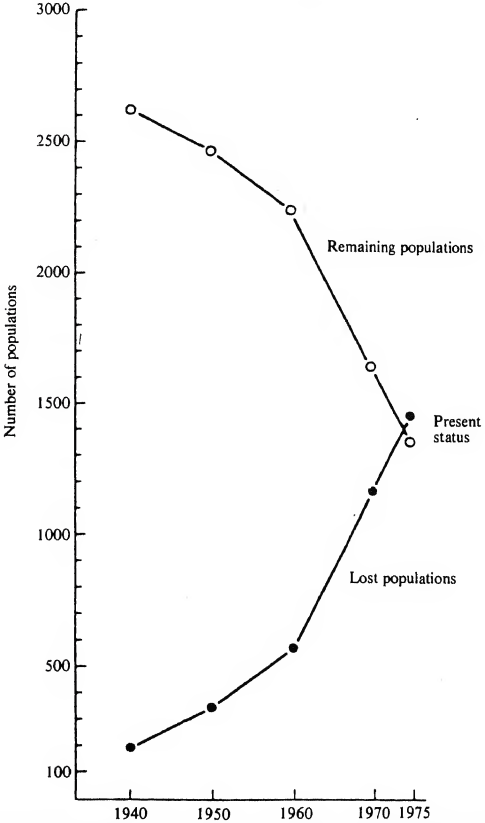
FIGURE 5

Variation of discharge and some chemical components during 1980 at Langtjern.



Source: Norwegian State Pollution Authority

FIGURE 6
BROWN TROUT
Population Changes



Time trend for population losses of brown trout in the affected areas in the four southernmost counties in Norway. 'Recent changes' refer to changes during the period 1974-1979. (Sevaldrud and Muniz, 1980).

23,000 miles have been acid-altered—18 and 20 per cent respectively within areas considered sensitive.[49]

3 *The causes of damage*

45. In this section we consider how fish die, and whether those causes can be attributed to SO_2 or NO_x emissions.

(a) *How fish die*

46. Many life forms upon which fish depend for food are affected by a lowering of the pH of water. For example, the number of species of snails in 1000 Norwegian lakes is 20 at pH 7, and 0 at 5 (see Fig. 7 on page xxix). A wide variety of invertebrate species only survive at over pH 5.7 which is the critical pH zone for the biota so crucial to the aquatic food chain.[50] Fish populations die in one of two ways: either because the pH becomes too low for their food stocks to be maintained, or because pH levels, often in snowmelts, are too acidic for eggs to hatch, fry to survive, or for the fish themselves to live. Fish are directly affected when they fail to take up salts through their gills, and sodium deficiencies result. In addition aluminium, which goes into solution when pH falls below a certain level, especially in the absence of calcium stimulates excessive mucus production resulting in physical clogging of gills and suffocation. The importance of all three features-pH, calcium levels, and aluminium levels was emphasised to us by DOE's Chief Scientist [51] and by Scandinavian scientists.

(b) *the role of pH*

47. Some fish species are more tolerant to low pH levels than others. A study of fish populations, however, shows that the average age and average size of those fish tends to rise as pH falls, until pH reaches the point at which all fish die. Experiments have shown that fry and eggs are more sensitive to low pH than adult fish and die off first. Snowmelt is crucial here: the time of year for eggs and fry is when the most acidic surges occur. Increased acidity alone will kill fish below pH 4 and these levels have been reached during snowmelt.[52] The diagram on p.xxx (Fig. 8) shows this effect.

(c) *Calcium*

48. A common feature of fishless lakes is low calcium levels.[53] This mineral is crucial to fish life. The CEGB have established that fish can live in lakes with low pH if there is a significant calcium presence. It has been proved also that the artificial addition of calcium by liming to lakes will slow fish kills. Liming of lakes is being extensively developed in Scandinavia as a stop gap until emission controls result in reduced pH.

(d) *Aluminium*

49. Aluminium is highly toxic to fish[54] although some doubt exists over which forms of aluminium are most critical.[55] It is most toxic at a pH of about 5.0. In soils

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[49] Acid Rain and Transported Air Pollutants, Office of Technology Assessment, June 1984 (hereafter cited as OTA), pp 207-16

[50] Acid Rain and its effects on the Lake District, D. W. Sutcliffe, Freshwater Biological Association

[51] Q215-218

[52] ETSU, 85

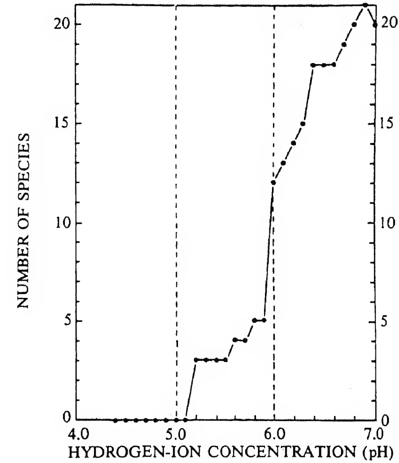
[53] Q82

[54] see para 46

[55] Freshwater Biological Association.

FIGURE 7

Decline in snail species as acidity increases in 1000 Norwegian lakes



it goes into solution at between pH 4.5 and 5.0. It cannot therefore be considered in isolation from the pH of rainfall. Low pH rainfall, particularly where conditions for buffering are poor, slowly acidifies the soil and makes aluminium more soluble. Soil scientists in Sweden gave us extensive evidence of the leaching of aluminium from soils due to acid rain.

(e) *Summary*

50. It is evident that acidification of the habitat of fish is disastrous to them, especially where aluminium is present and calcium is not. At the same time the pH of rainfall is not the only factor involved in the acidification process. Arguments have been advanced to suggest the prime culprits are afforestation or the soil itself and these we consider next.

4 *How important are factors other than acid rain?*

(a) *afforestation*

51. Forests often increase the acidity of rainfall as it passes through the tree canopy.[56] Some evidence suggests that groundwater running out of forest catchments is more acidic than in unafforested soils.[57] Trees, particularly conifers, collect and hold dry deposition during dry periods. When it rains these acid deposits dissolve and pass through forest canopies to the soil.[58] This pheomenon

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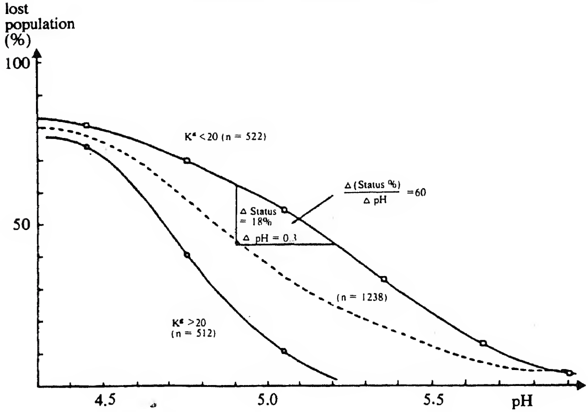
[56] Ev, pp 251
[57] Q212
[58] Institute of Terrestrial Ecology, Gisburn project

FIGURE 8
Trout populations fall as acidity increases (Norway)



appears to vary with the species of trees planted. There is also evidence to suggest that when trees are grown as a crop their complete removal takes with it alkalis which would otherwise return to the soil in a natural, unmanaged life/death cycle. Thus forestry as an economic activity tends to increase acidification of the soil through which rainwaters run into streams and lakes. This contributory factor heightens the effect of acid rain, which varies variably with different soils in different areas. In Scandinavia witnesses said that reductions in atmospheric pollution would also lead to reductions in any role in acidification from afforestation.

52. However, acidification was first observed in Scandinavia at altitudes above the forest line. Evidence from Galloway in Scotland suggests lakes became acidified which had no forests around them.[59] Streams in Birkenes in Norway have become more acidic despite being in wild forest that has not been harvested.

(b) *buffering of soils*

53. The role of soils, in particular in relation to long-term acidification, is immensely complicated. Some general observations can be made. The condition of soil is crucial. If the geology of the lake catchment area is igneous rock, for example granite, then the run-off of acid rain is not neutralised, by contrast to where it soaks through soils relatively rich in calcium. If the soil is thin over rocks which weather very slowly, then neutralising agents are eventually leached out of the soil by persistent exposure to acid rain. This was shown to us in the results of

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[59] AR 59

tests in southern Sweden conducted by Professor Tamm[60] and his father since 1927. The presence of alumunium and other toxic metals add to the problem. It is undoubtedly true that poor soils are characteristic of areas suffering acidification. Such environments are often finely poised. The result is that relatively small changes—such as climatic stress or a fall in rainfall pH—can have significant effects for freshwater life.

(c) *Summary*

54. The Department of Energy report concluded "that acidity deposited from the atmosphere, enhanced by the effects of local coniferous afforestation, acid soil and slow weathering geology, makes a significant contribution to damage to aquatic life".[61] Without acid deposition, none of these factors would cause the scale and suddenness of damage to aquatic life being observed now: they do not, for example, in northern Norway.

5 *Remedial measures*

(a) *Liming*

55. A widely-used method of counter-acting the effects of acidification is to add calcium, usually in the form of lime, to water. This raises the pH of the water and lowers the amount of aluminium in solution. Liming has resulted in the recovery of some Swedish fisheries and enabled some lakes to be restocked. In Sweden 278 lakes were limed between 1977 and 1984. Some experimental work is underway in Norway.[62] The CEGB told us in evidence[63] that the addition of lime to all "at risk" lakes in Sweden would cost about £18 million per annum, far less than emission controls, and have a more certain effect.

56. Liming has practical disadvantages. Given the scale of the problem DOE advised us that it is not a practical solution.[64] Anyone who has flown over southern Norway and seen the number of damaged lakes in remote locations where there are no indigenous sources of lime would realise this. In any case, turn-over of water in lakes in Norway is up to four times faster than in Sweden; hence more frequent liming would be required.[65] Liming does not work effectively in streams—precisely those areas which are critical for trout and salmon breeding. It does not deal with snow-melt.

57. Liming also has ecological disadvantages. Important fish food types can be lost or reduced. The addition of calcium to a lake does not prevent the leaching of toxic aluminium from soils, but merely causes it to precipitate to the bottom of the lake. If the liming is stopped then a further fall of acid rain brings back the aluminium into solution and it would then kill off fish with which the lake had been restocked. Some fish do not breed in limed waters. Lastly, there is little knowledge of its ecological effect when used over a long period.

58. Liming leads to some immediate improvement in fish stocks. However, there are substantial disadvantages, not least the number of critical locations where it cannot be used effectively. Swedish scientists made it quite clear to us

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[60] Of the University of Agricultural Science, Stockholm
[61] ETSU, p85
[62] The Norwegian Liming Project
[63] Q 84
[64] Ev, p 69
[65] Dr. Aunnerod

they were pursuing liming as a temporary measure only, until controls reduced emissions and depositions. The CEGB and CBI want it now until all scientific uncertainty has been resolved. We conclude that liming cannot be used to halt, even temporarily, most of the damage to freshwater life caused by acid rain. It is only a palliative, not a permanent solution.

(b) *Reducing depositions*

59. Whilst in Norway, we examined experimental work in the field to assess the effect of reduced acid deposition on the pH of surface water. The Norwegian Institute for Water Research[66], from a survey of major-ion chemistry and fish populations in 683 lakes in southern Norway, has demonstrated that a 30 per cent reduction in sulphur deposition would restore chemical conditions to such an extent that 22 per cent of the lakes without fish life should be able to support fish. A 50 per cent reduction would restore 35 per cent of the lakes and a 70 per cent reduction would restore 49 per cent of the lakes. A later study demonstrates that even a moderate pH increase of 0.2 units in lake water would cause a considerable improvement in fish status in Southern Norway. The Steering Committee of the Norwegian Liming Project confirmed that the problem would only be alleviated by reduced depositions. The Report of the 1982 Stockholm Conference—Expert Meeting I—came to a similar conclusion.[67]

6 *Conclusions: the need to reduce depositions*

60. Alleviation of the problems caused by acid deposition to surface waters in Scandinavia requires reduced depositions. Whilst the role of water-catchments complicates full knowledge of chemical processes, there is little dispute over the significance of acid rain, even given local factors such as afforestation. The 1982 Stockholm Conference concluded that "continual high inputs of acid deposition must lead to reduced neutralisation capacity in susceptible soils, and hence to further freshwater acidification".[68] A reduction of depositions by a 30 per cent would have direct beneficial effects. However, whether a given level of reductions in emissions would achieve a 30 per cent reduction in depositions is very difficult to evaluate. This we discuss later.[69] Action from countries other than the United Kingdom is needed, even though we may be the worst polluter of Scandinavia. Lack of action by other countries does not give this country an excuse to carry on polluting others in breach of the Convention on Long-range Trans-boundary Air Pollution. Our action would need to centre on those sources of emissions who are responsible for long-range pollution, principally the CEGB, whose emissions have not fallen since 1970.

61. Whilst the problem is extremely severe in Scandinavia, in the United Kingdom we are fortunately less vulnerable in most parts of the country because of geological and climatic factors. We turn now to consider the problem here.

Damage to freshwater life in the United Kingdom: the risk and the actuality

(i) *the areas at risk*

62. As in Scandinavia, the areas at risk are those in which soils or bedrock have limited buffering capacity. Parts of Wales, Scotland and the Lake District are particularly vulnerable. Substantial falls in the diversity of life in streams occurs

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[66] Wright and Hennriksen
[67] p 16
[68] p15
[69] para 129 ff

when the mean annual pH falls below 5.7.[70] A result may be insufficient food for fish. Some natural acidification is occurring, but the Freshwater Biological Association (FBA) emphasised that this has been continuing for thousands of years, and is thus not likely to cause significant pH falls over a short period.[71] As Scandinavian evidence demonstrates, snowmelt or high rainfall episodes are critical. The FBA, on the basis of laboratory work, concluded that "the episodic occurrence of low pH values, acting in combination with other factors . . . is likely to reduce the survival of eggs and young fish in the upper Duddon and similar mountain areas".[72]

(ii) *Acid rain is having an effect on freshwater life in the UK*

63. We received evidence that increasing acidification is being caused by deposition in this country, and that it is having an effect on freshwater life. Professor Last of the Institute of Terresterial Ecology advised that pre-industrialisation most acid streams in this country still had a pH as high as pH 5. Now many Lake District and Scottish streams have lower pHs in which low-level aquatic fish life cannot survive.[73] Anecdotal evidence from the Lake District, Galloway and Wales of declining fish catches points to the existence of a problem. Monitoring of snowmelt shows this. The Freshwater Biological Association advised that acidity in upland streams would fall by pH 1–1.5 in winter flood.[74] Work by the North West Water Authority associated the high flows after dry periods (and hence long periods of dry deposition of acids) with substantial falls in stream pH. Similar evidence came from the Macaulay Institute on Soil Research,[75] which has demonstrated that for acidity to reach a stream water must drain very rapidly through or over the soil, as it does in snowmelt.[76] In Galloway, at Loch Dee, monitoring has shown a pH drop in two feeder burns to below pH5 for 30 per cent of the year, causing damage to invertebrates. During snowmelt, the main spawning burn has had a similar fall.[77] Death of fish fry has resulted, as in Scandinavia. Similar problems have been monitored in more remote lakes by the Nature Conservancy Council and by the Welsh Water Authority.[78] Acid deposition is therefore affecting fish stocks in areas where the geology of the catchments offers little natural buffering.

64. The Nature Conservancy Council has documented the threat to many other forms of aquatic life. The result shows a diminution in food for fish, a consequent diminution in fish stocks, and in bird life. The length of dipper territories alongside water in southern Scotland has increased coinciding with a growing scarcity of their natural food. The Welsh Water Authority has observed the same effect on dippers in Wales.[79] Fish losses due to acid deposition are partly responsible also for the surprisingly low level of otters in Galloway compared with the apparently less favourable Highland Region.[80]

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[70] AR 47
[71] AR 26
[72] ibid.
[73] Q528
[74] Q571
[75] Q577
[76] AR 42
[77] Solway River Purification Board
[78] AR 53
[79] AR 53
[80] NCC, op, cit., p 31

(iii) *the role of afforestation*

65. Evidence of acidification shows that here, as in Scandinavia, which we discussed in para 53, forests exacerbate the effects of acid deposition on surface waters, but do not cause it. The Welsh Water Authority told us that in Wales many afforested upland catchments could no longer support natural fish populations.[81] However, again as in Scandinavia, acidification of streams and lakes has occurred in this country in unafforested catchments and lakes. In Galloway, evidence is that acidification occurred contemporaneously with industrialisation.[82] The FBA thought that although lakes in the Lake District had not become more acidified in the last 50 years,[83] they had probably become more acid during the period of industrialisation than they would otherwise have been. This is confirmed today by the significance of weather from the South East—that is, the industrialised parts of northern and central England—to the acidity of precipitation in both the Lake District and Galloway.[84]

(iv) *evidence of fish losses in the UK*

66. In addition to declining catches reported by fishermen in Scotland, Wales and the Lake District,[85] fish losses have been reported by fish farmers in Scotland and Cumbria.[86] Mr G Gordon, a member of the NFU of Scotland who met us in Galloway, had farmed on the River Ken in Galloway for twenty years, and began to experience episodic and unexplained fish kills twelve years ago. Two years ago he commissioned the Institute of Aquaculture at the University of Stirling to investigate and they concluded that "the site has been subjected to increasingly serious mortalities, often associated with snowmelt and flood waters . . . correlated with toxic aluminium concentrations and low pH in the farm water supply."[87] One such loss amounted to 20,000 fish. Similar effects have been observed elsewhere in this country.[88]

67. An additional possible cause of fish damage was put to us by the Solway River Purification Board at Loch Dee, in Galloway. Their scientists suggested that the deposition of sea salts during storms might be relevant. The sodium in these salts releases acidity already present in the soil. Sea storms could not of themselves explain damage there because acidification had accelerated in the previous fifteen years, whilst deposition of sea salts had not changed at all. The additional acidity must therefore come from continual acid rain.

(v) *Conclusions; reduced depositions are needed to safeguard the UK's freshwater life*

68. Surface waters in remote areas with little buffering are becoming acidified. In part this is due to very slow natural processes. However, episodes of acidity, which are almost entirely attributable to man-made pollution, appear to have increased in intensity in these areas. It is these episodes which appear to be responsible for the recent increase in damage to freshwater life here as in Scandinavia. The fall in SO_2 emissions since 1970 is not likely to have been as

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[81] AR 53
[82] AR 59, Q537
[83] The NERC do not consider this conflicts with the evidence in Scotland for acidification of lakes in the Galloway area, where there has been a change (Q581).
[84] Q557
[85] Q537
[86] AR 44
[87] Ev. not reported
[88] NFU (Scotland)

significant in rural areas because of the high stacks policy. Moreover there has been an increase in NO_x which contributes substantially to rainfall acidity—for example, ⅓ to ½ in the Lake District. Liming of streams to cope with the high floods which are so damaging is difficult both for technical reasons and because of the remoteness of many of the sites affected. Fish will still die because of factors totally unconnected with pollution, such as drought. Nevertheless, a substantial reduction in SO_2 and NO_x emissions is therefore needed to safeguard the diversity and richness of freshwater life in this country.

C. *Trees*

69. In this section we assess the extent of damage attributed to acid rain, the species affected, the symptons observed, the speed at which damage spreads and the effects in leading to secondary causes of death. We then assess various theories advanced to explain the damage, and conclude that there is a key role for air pollution. We end by assessing the extent of damage so far observed in this country and whether there is any risk of damage occurring.

1 *The acid rain problem*

(i) *The extent of damage*

(a) *West Germany*

70. Damage to forests in West Germany began to be observed in the 1970s. It was initially seen in Bavaria and Baden-Wurttemberg and has intensified since 1980. A survey in 1982 showed 8 per cent of the total forest area of West Germany was affected. A 1983 survey showed this had risen to 34 per cent[89] and during our visit we were told that the 1984 figure would be over 50 per cent. Even allowing for the effects of weather and sampling error, there has clearly been a huge and widespread increase in damage which cannot be categorised according to previous experience. Areas affected are spread over much of the country, and are usually distant from emission sources. We were told by Baden-Wurttemberg forestry officials that 300,000 hectares in the Black Forest show every tree damaged. There is also damage to forests in the eastern Bavarian Alps, and this is partly blamed on Czechoslovak emissions.

(b) *Scandinavia*

71. A survey of all 12 counties in south and central Sweden in the winter of 1983 reported 244 damaged stands of trees. A sample survey since has extrapolated a damage area of 17–18 per cent.[90] There has been a report of damage to forests in Norway, although to date it has not been confirmed.

(c) *Other parts of Europe*

72. Damage has been observed in central and eastern Europe, where there are high local levels of SO_2 emissions. Some damage has been reported in Austria and France, and serious concern exists in Switzerland.[91]

(d) *North America*

73. Recent declines in several species have been observed in many parts of the Eastern United States.[92]

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[89] FRG Munich Multilateral Conference Paper
[90] Evidence not reported (Swedish National Forestry Board)
[91] Acid Rain, Environmental Resources Ltd
[92] OTA, pp217–38

(ii) *Species affected*

74. Earliest German reports showed fir populations initially affected, but since then damage to spruce in the main pine and beech has been observed. Other species have also suffered damage, including oak, maple and ash. In the Black Forest all species of trees are now thought by forest authorities to be affected. The older coniferous trees suffer first and in the Black Forest saplings were showing damage on removal of the shelter previously afforded them by older trees. In Scandinavia spruce is also the main tree affected and, as in West Germany, the older trees suffer first.

(iii) *Symptoms observed*

75. Initially, trees whose tops are exposed above the forest canopy show effects, spreading to all trees in stands. Different trees are affected at different rates. On spruce, top growth slows, resulting in a "stork's nest" effect. Side-branches die. Needles yellow, usually on the upper side of branches, and then fall off. Growth appears stunted and side branches die. In deciduous trees, leaf discolouration, early leaf fall, death of tree tops, damage to bark as well as lack of natural rejuvenation are observed.

(iv) *Speed at which it occurs*

76. One of the most disturbing features is not only the extent of damage but also the suddenness with which it occurs and increases. German forestry experts gave us the results of monitoring in sample areas where every tree had been observed since 1977. Health was graded by needle loss. A tree is not expected to recover if needle loss exceeds 50 per cent. A survey of spruce showed this,—graded by percentage needle loss:—

Percentage of trees in three grades of health:

	Healthy	Ill	Dead
Percentage needle loss:	0–10%	21–60%	100%
Autumn 1980	100	0	0
Spring 1981	95	1	0
Autumn 1981	90	2	0
Spring 1982	50	10	0
Autumn 1982	5	40	0
Spring 1983	0	80	0
Autumn 1983	0	90	1

Trees are usually cropped before death and this leads to misleading by low figures for dead trees. The rapid acceleration towards serious damage is evident. Similar trends have emerged with different species. The Swedish survey showed 50 per cent of spruce and 77 per cent of pine on affected stands to be in a stage of 10–25 per cent damage.

(v) *Death*

77. Trees are usually cropped before death to prevent fungal attack and, in particular, bark beetle from destroying the commercial value of wood. Death, if a tree is left, usually occurs through these secondary factors. In the Black Forest we visited a hill-top which had been left in order that foresters might observe the effects of the damage if it took its full course. It was totally denuded. Foresters deeply fear a similar trend elsewhere.

(vi) *Economic Consequences*

78. Almost one-third of the land area of the United States is commercial timberland.[93] In West Germany, where a quarter of the country is afforested (compared to 5 per cent in the UK), 850,000 people depend on forestry for a living.[94] The Union of German Forest Owners' Association estimated present losses at £250–300 million per annum. The National Federation of Forest Owners' Associations in Sweden said many of its 250,000 members would suffer economic loss, and were having already to cut down trees too early.[95] 80 per cent of Swedish timber is exported. The short-term effect of felling is, of course, to increase timber quantities, but shortages will follow in the medium-term, pushing up the prices of a commodity of which the UK is a large importer. In Switzerland there is concern that once forests are lost at high altitude in the Alps, as is happening now, soil erosion will follow and it will be impossible to replant affected areas. Avalanches may increase in the absence of forests.

(vii) *Summary*

79. Forest damage in Europe is extensive, accelerating and of immense economic significance. In addition, other serious ecological problems may follow deforestation. We turn now to consider causes of damage, before considering whether and which reductions in emissions would slow down or reverse this damage.

2 *Different reasons advanced to explain tree damage*

Introduction

(i) *SO_2 deposition on trees*

80. Evidence from the United States based on research in the laboratory and in the field has demonstrated that prolonged exposure of trees to SO_2 is injurious.[96] No CEGB research has exposed trees for more than a year.[97] Evidence from eastern Europe and the southern Pennines demonstrates that high SO_2 levels do damage trees but that that damage may be reversible.[98] The interest of the American evidence and of research in this country by Professor Rutter of Imperial College, London,[99] is that it shows that lower levels of exposure over long periods also constitute a stress. In addition, work on occult deposition (fogs, mists) has shown it is often up to ten times more acidic than rain. The higher altitudes of the Black Forest are particularly prone to this. The 1982 Stockholm Conference concluded that tree growth could be reduced by annual mean concentrations of SO_2 as low as 25–50 microns SO_2 (9–18ppb): these concentrations prevail in much of Europe. Little is known of whether SO_2 depositions have a cumulative effect although we have received evidence to suggest they do.[100].

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[93] OTA, p 224
[94] Government of Baden-Wurttenburg
[95] Evidence not reported
[96] OTA, p 225
[97] Evidence from Central Electricity Research Laboratory
[98] Q505–8
[99] AR 15
[100] ibid

(ii) *Soil acidification by SO_2*

81. In Scandinavia and West Germany damage has been observed principally on trees on poor soils and, initially, at high altitude. In the late 1970's soil acidification by sulphur depositions was advanced as the prime cause of this damage. It was suggested that the acids released toxic elements in the soil, particularly aluminium, which cause damage or death to fine tree roots. In consequence the trees became starved of various nutrients, such as magnesium.[101] We received evidence in Sweden that showed long-term acidification of soils occurred between 1927 and 1983 in areas with both natural and managed forests of different species. It was also shown that this was substantially reversed after felling.[102] New forestry practices in this country take account of this by leaving bark branches and needles where trees have been felled to return nutrients to the soil.[103] However, damage has been observed also in areas where soil, although poor, is not acidic, and where SO_2 depositions are lower than the level considered injurious to forest growth.[104] This has indicated that there may be causes of damage other than soil acidification by SO_2.

(iii) *Ozone*

82. Increasing attention has been given in recent years to the role of ozone. This develops from NO_x, which is emitted by power stations and motor cars. German experts at the Ministry of Science and Technology said traffic densities in central Europe where there are no speed limits meant NO_x and ozone levels were high there. Engines produce more NO_x the faster they go and the hotter they get. Hydrocarbons, also emitted by motor cars, are important elements in the complicated atmospheric chemistry by which ozone is formed. A major role for air pollution is suggested by the widespread nature of damage to trees on different types of soils and in areas not necessarily affected by high SO_2 levels. It is also suggested by the damage in the Black Forest to saplings exposed to sunlight after older and taller protective trees have been removed.[105] American evidence has demonstrated that comparatively low-level ozone concentrations affect trees.[106] A volume of 50 parts of ozone to each billion parts of air (50ppb or 136 microns) is generally regarded as the maximum natural concentration. Concentrations as high as 200 parts per billion have been recorded in southern Sweden. Levels occur in West Germany similar to those shown to be damaging by the US research.[107] In the US ozone is thought to be contributory to damage to trees observed in the eastern part of the country.[108]

83. Ozone levels are highest on hot sunny days, especially during periods of anti-cyclone. This may explain why damage is accelerated during dry summers such as 1976, when trees are already under stress by drought. In Germany even during normal rainfall years high ozone incidents still occur. The northern parts of the British Isles probably have lower ozone levels than Germany due to wetter weather and more frequently overcast skies. However, in south-eastern England high levels have been recorded, some of which comes across from the Continent.

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[101] AR75
[102] Work of Professor Tamm, University of Agricultural Science, Uppsala
[103] Q476
[104] Prof F Andersson, University of Agricultural Science, Uppsala
[105] Q463
[106] OTA, pp 225–6
[107] Q175
[108] OTA, pp 225–37

Ozone levels are known to be highest at mountainous altitudes, where the air had been thought to be pure and free of pollutants. Tree damage has been observed in such areas: this was regarded as inexplicable until the role of ozone came to be better understood.

Summary: a combination of factors cause damage, but SO_2 and NO_x are crucial

84. There is a good deal of doubt over forest damage, especially in the search for a single cause. However, the indications are towards a combination of ozone, wet and dry depositions of SO_2 and NO_x and their derivatives, soil characteristics and climate. Recent research has shown, for example, that ozone predisposes trees to damage by acid precipitation, including occult precipitation.[109] This conjunction of ozone and acid mist occurs in the Black Forest.

85. Air pollution is present in all areas where forests show stress. It is also present in some that do not. This suggests that other factors are also significant, such as soil acidification. The DOE's Chief Scientist concluded that in West Germany, where most tree damage was encountered, it was probable that air pollution was involved[110], but that the dominant air pollutant involved is not necessarily the same in all places.[111] However, all these pollutants are, or are derived from, SO_2, NO_x or hydrocarbons, the products of fossil fuel combustion.

86. Trees are subject to many stresses: the acidity of rainfall, wet and dry deposited pollutants, ozone, nutrient deficiencies, drought, frost and wind. An excess of any one of these, Dr Nillson, a Swedish forestry expert, told us[112], was likely to reduce the capacity of a tree to resist other stresses and attacks from their natural enemies such as insects and fungi. He likened a tree to a cup full of stresses. To reduce one would lessen the risk of the cup overflowing and the tree suffering damage. Different areas have different combinations of stress. Thus occult mists are not a problem in southern Sweden, just as SO_2 depositions may not be a serious problem in the Black Forest. This strongly supports the need to reduce the range of stresses trees suffer, and points to improved forestry practices, SO_2 reductions, NO_x reductions to achieve lower ozone levels, and hydrocarbon reductions to minimise the effects of ozone.[113]

87. The key question is whether any benefit would result from reduced depositions or emissions. Taking the various stresses separately, the weight of evidence suggests, yes. If aluminium is critical, then the less SO_2 or NO_x deposited the less aluminium will be released. Also, reductions in SO_2 and NO_x will assist the buffering capacity of soil to reverse its decline in pH in the long-term. Lastly, if NO_x and hydrocarbon levels fell, so too would ozone levels, and the likelihood of their causing damage would be reduced. Trees can recover from acid rain if damage has not progressed too far and be prevented from suffering damage provided the programme to achieve it takes account of the roles of both SO_2, NO_x and hydrocarbons in causing stresses additional to natural stresses.

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[109] Leaching of minerals, incuding magnesium, from the leaves
[110] Q204
[111] Q205
[112] Evidence not reported
[113] AR 36

3 *UK Forest Damage*

88. In the United Kingdom we visited Cumbria and saw evidence of damage to trees in the Lake District. A survey for Friends of the Earth (Scotland) by a German expert concluded that 'official statements that Britain is unaffected by acid rain—related tree damage are completely inaccurate; we have to conclude that the Government has either failed to appreciate the potential for environmental damage by acid rain . . ., has withheld information or is unconcerned about the problem'. However, when the survey was presented to us orally, it was emphasised by a Friends of the Earth (Scotland) representative that we were not to presume acid rain was necessarily the cause of the damage.

89. Forestry Commission officials have observed extensive die-back of shoots on Scots pines, evidenced by browning of needles. This is extremely widespread at the site we visited in Whinlatter Pass in Cumbria. Some damage was also observed to Norway Spruce and Sitka spruce. A minority were badly damaged enough to be at risk of dying. Officials said similar damage had been observed in the past, but not on anything like a comparable scale.

90. Forestry Commission officials told us that fungi were not the cause of the damage we saw. They thought that the conditions of the previous winter (high winds associated with low temperatures) might have been responsible for much of the damage. However, they could not explain the damage to Sitka spruce in this way. This unexplained damage gave them cause for concern, although it was not similar to damage to trees observed in West Germany. We can draw no firm conclusions from what we observed in Cumbria, although there are some features in common with German and Swedish damage which we and local Forestry Commission officials found disturbing. As we have said, one of the main features of acid rain is that it predisposes trees to other stresses with which they might otherwise have been able to cope.

91. Taking the United Kingdom as a whole, the Forestry Commission asserted that it saw no evidence of damage due to pollutants in this country. However, it did warn that 'it is not certain that damage may not have occurred or that it will not occur. Trees grow slowly . . . and even . . . reduction in annual growth of 20 per cent is difficult to detect . . .' it was concerned that in areas with acidic soils higher acidic inputs than normal may be having effects: 'this could, if continued unabated or even if continued at lower levels, have deleterious long-term effects in root growth and nutrient uptake, leading to reduced growth'.[114] In addition, the mean levels of exposure to SO_2 which the International Union of Forest Research Organisations believes can inhibit groth (>25–30 microns or 9–18ppb) occur over much of rural Britain. It is clear that professional foresters here feel there is a risk, and would feel more secure that risk were lessened.

92. The weight of firm evidence received to date is that there is no forest damage in this country other than that due to relatively localised high SO_2 levels. The likelihood of such damage is difficult to assess due to the absence of a proper rural monitoring network for SO_2, NO_x and ozone.[115] The south-east of England,

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[114] Ev, p 201, Q504

[115] Q567

where ozone levels are thought to be higher than in the rest of the country, has fewer climatic stresses than affected areas on the continent of Europe. We are concerned, however, that in S. Sweden damage was suddenly discovered in 1983 covering around 17 per cent of the forest area. This discovery was the result of West German experts briefing Swedish district foresters on symptons of this damage, who then went back to their areas to survey for it. Swedish and German experts then examined the district forester's report, looked at the cases in the field, discounted a proportion of them as due to other causes but were nevertheless left substantial evidence of damage attributed to acid rain and/or ozone. No such survey had been done here. Many of the areas at risk are remote. **We recommend that the Forestry Commission, using its own and West German experts, conduct a survey on the same lines as that in Sweden forthwith.**

93. We were somewhat surprised to find that, despite the experiences of other European countries, the Forestry Commission is doing no research on ozone damage[116] and seems to have exerted little or no pressure to improve the monitoring network or to commission research.[117] Certainly, soil acidification, acid rain and deposition of sulphates observed in damaged parts of Europe do occur here, but little ozone or NO_x monitoring exists to assess whether this crucial additional stress is bein experienced here. Some work has been done by the Institute of Terrestrial Ecology.[118] We believe that it is quite wrong to delay research unless or until damage has occurred. It is not acceptable for the Forestry Commission to argue its own role is simply to notice damage. **We recommend that the Forestry Commission undertake detailed NO_x and ozone monitoring and begin research into acid rain and trees.**

D *Effects on plants*

94. Environmental Resources Ltd, in a cost-benefit analysis commissioned by the European Commission, set loss of crop value at £670 million per annum in the Community, higher than any other category of damage except buildings. We find it difficult to place any reliance on this figure since it is based upon an unsubstantiated assumption that acid rain causes an average 10% fall in crop yield. Nevertheless, scientific evidence of a dose-response relationship for crops should be less difficult to obtain than for virtually any other ecological form of damage attributed to acid rain. In this section we assess US and British evidence on SO_2, NO_x and ozone damage, to see if this is likely to have caused any fall in crop yield. Separately, we assess some examples of plant damage which have no apparent economic value at all.

(a) *agricultural crops suffer reduced yields*

95. The Ministry of Agriculture, Fisheries and Food told the Committee that 'there is no evidence at the present time of discernible damage to UK agriculture in general'.[119] We consider this complacent, and founded upon little other than conjecture. As we have discovered, experimental and field data from this country and the US point to the main effect of ozone on crops being a reduction in yield but not visible symptoms of damage.[120] There is very little ozone monitoring in this country. It is therefore difficult to say whether critical damage levels have or have not been regularly reached over the country as a whole. There is equally little evidence that ozone is not damaging UK agriculture.

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[116] Q511–3
[117] Q466
[118] AR 48
[119] AR 23; Q201
[120] OTA, p 225

96. US research has demonstrated that acid deposition has a visible injury threshold on crops at between pH 2.0 and pH 3.6, depending on the species. Warren Spring Laboratory's evidence is that rainfall at so low a pH does not occur in this country except in short episodes[121]. Growth effects also occur between pH 3.5 and 4.0. The US Environmental Protection Agency has monitored ozone levels at over 500 sites, during the growing seasons of crops. This has been correlated with field experiment data to assess potential gains in productivity achievable if ozone levels were reduced to an estimated natural background level of 25 ppb. Yield increases for wheat in different states ranged up to 10.2 per cent. the national average being 5.38 per cent, worth $125 million.[122] For maize the figure was 2.4 per cent, worth $361 million.[123] Figures are far below the claims made by ERL.

97. Research by Professor Mansfield of Lancaster University has demonstrated that the dry deposition of SO_2 and NO_2 affects plant growth.[124] It is based on the effects of concentrations over 40 ppb (or 109 microns), which occur around the major cities of western Europe. The combined action of the two is often greater than the sum of their separate effects, again emphasising the significance of rising NO_x emissions. Root growth appears to be particularly severely inhibited. Much work needs to be done, but the effects were worst when plants grew in stressed environmental conditions. Low levels of each may, however, be beneficial.

98. In the United Kingdom we received evidence from Dr M R Ashmore of Imperial College, London, on ozone effects.[125] Ozone levels in unpolluted areas in this country are typically 20–40 ppb. However, in most summers they exceed 100 ppb on occasions, with a recorded maximum of 250 ppb in the hot summer of 1976. These higher concentrations are the result of chemical reactions involving NO_x and hydrocarbons. These latter concentrations are comparable to those which occur in parts of the eastern USA where ozone damage to vegetation is a familiar phenomenon. Indeed, visible ozone injury caused by the ambient air of south-east England has been demonstrated by Dr Ashmore in experiments with peas and clovers.[126] Similar symptoms have been observed in the field on beans, grapevines, spinach, tomatoes, alfalfa and peas. It is estimated that the threshold concentration for such growth reductions is only 60 ppb on more than 10 per cent of days in the growing season. This level—which, it should be emphasised, reduces yield but does not cause physical damage—was exceeded on 15 per cent of days in seven of the last eleven summers in south-east England.

99. The Department of Energy Report makes virtually no reference to ozone damage to crops, except tht radishes can 'adapt to ozone levels of 170 ppb (452 microns) continuous exposure, although with a loss in root volume'.[127] That, of course, is the edible and economically significant part of the radish!

100. Existing evidence therefore points to crop damage in the form of reduced yields in this country. These yields would be enhanced if ozone levels fell and dry

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[121] AR20
[122] OTA, p 225
[123] ibid
[124] AR 50
[125] AR 36
[126] ibid
[127] ETSU p 90

deposition of SO_2 and NO_x were reduced. Most of the pollutants affecting crops in this country are emitted here, so a direct benefit would follow the imposition of controls. Unfortunately, due to the complexity of environmental interactions, 'a dose-effect' relationship in the field is difficult, if not impossible, to establish.[128]

(b) *other terresterial flora*

101. Lichens are one of the few groups of plants of no economic value to have been extensively studied. Most are extremely sensitive to atmospheric SO_2, and many also to acidity. They are therefore very good indicators of the acidification of an environment by wet or dry deposition. Much of England is effectively a lichen desert due to dry SO_2 deposition. The Nature Conservancy Council and the British Lichen Society[129] submitted evidence of the loss of lichen species because of acid rain over most of Britain. The NCC argued that any modification of lichen communities due to acid rain "is likely to represent a significant loss of conservation value."[130]

102. The British Lichen Society gave examples of the effect of high urban SO_2 levels. In 1865 Epping Forest, which is downwind of London's polluted air, had over 120 species but now has only 28 species of which only 2 live on tree bark. This suggests that the air in Epping Forest once experienced levels of less than 30 microns (11 ppb) of SO_2 in the air but that these now exceed 125 microns (47 ppb). Furthermore "in regions of naturally high acidity but low air pollution, such as Dartmoor, much of central and north Wales, and Scotland, abundant lichen floras are found. One can expect over 300 species per 10 square km in such places."

103. The communities of greatest conservation value are therefore in remote areas which receive a high proportion of sulphur through wet deposition. We visited two such sites in the Lake District. At Greatwood, in Borrowdale, rare species on oaks survive, but at nearby Seatoller, with higher precipitation, species diversity on oaks had declined substantially. At least one species known in 1916 is now extinct, and certain of the species we observed in the Lake District no longer survive at altitudes over 180M as they once did.

104. The importance of Seatoller is that it is the finest woodland site in Northern England for lichens, with 182 species, and has been designated as a Site of Special Scientific Interest. Yet, in that wood species diversity is declining, and the Nature Conservancy Council told us there is no doubt that that decline is due to acid rain. Controls of our SO_2 emissions would increase species diversity and safeguard threatened areas. Unfortunately for lichens whilst they have great value conservationally, and to the variety and richness of our natural environment, they have no economic value.

105. The evidence of the British Lichen Society[131] did, however, show that lichens are making a cautious come-back into hitherto polluted areas, including Tyneside, London and South Yorkshire. This is a direct benefit of the effects of the Clean Air Act and the fall in domestic and industrial SO_2 emissions since 1970. The Society emphasised that "their recovery is due to man's activities, admittedly in ignorance." At the same time, however, the Society warned that industrial

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[128] AR 36
[129] NCC, op.cit; AR 52 AR 97
[130] AR 52
[131] AR 97

pollution could be expected to rise again, and lichens would suffer; they recommended, therefore, that "steps are taken to stop sulphurous pollutants escaping into the atmosphere".

106. Mosses are also susceptible to acid deposition which has caused some species to vanish from some areas. We received evidence from J A Lee of the University of Manchester[132] of the effects of acid deposition on blanket bogs in the southern Pennines. Due to the depth of peat on which they grow, they rely entirely on wet and dry depositions for nutrients. Sphagnum species, major peat formers have been virtually eliminated since the Industrial Revolution. The failure to re-establish the species suggests a cumulative effect that will take time to reverse. The fact of a cumulative effect may mean that over a longer period similar losses might occur at less polluted sites.

(c) *Conclusions: reduced emissions would benefit plants*

107. Available evidence on crops and other plant species suggests there is considerable cause for concern. Economically valueless plants have suffered, and the Nature Conservancy Council argued that it was likely that losses to plants other than the mosses and lichens which had been studied had occurred in much of the upland areas of the country[133], through wet and dry depostion and soil acidification. Not all benefits from reduced emissions can be quantified, still less given an economic value, and a dose-response relationship for different species may be impossible to attain. In summary, there would be environmental and ecological benefits to plants from reduced emissions of SO_2 and NO_x.

E *Damage to Materials*

108. According to the Department of Energy "increased concentrations of atmospheric pollutants have been found to accelerate the weathering and corrosion of many structural materials" including carbon steel, zinc and nickel.[134] Such damage is mainly due to the dry deposition of SO_2 onto exposed surfaces from local sources. Atmospheric corrosion is governed by humidity, temperature and the concentration of pollutants in the air. The table below compares the corrosion rates of metals in different environments. Unprotected carbon steel has been found to corrode rapidly in urban and industrial atmospheres.[135] Similar, but lower corrosion rates have bee found for zinc, galvanised steel and nickel.

Corrosion rates of metals in various environments

Atmosphere	Differential Corrosion Rate $\mu m\ yr^{-1}$				
	Carbon Steel	Zinc	Nickel	Copper	Aluminium
Industrial	40–70	4–6	6	2–5	0.2–1
Urban	20–30	1.7–3.7	1.8	1–2	0.1–0.2
Rural	10	1	0.25	1	0.1

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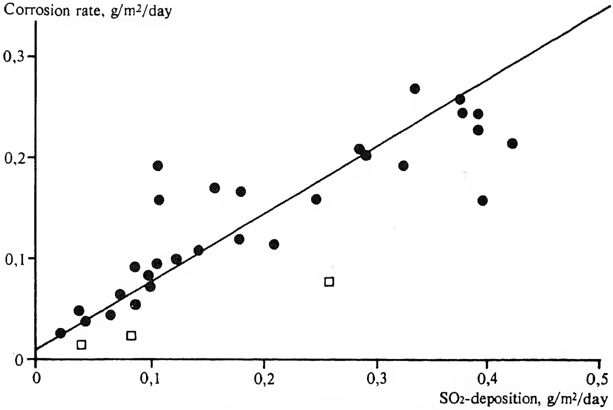
[132] AR 45
[133] NCC, op. cit.
[134] ETSU para 406
[135] ibid para 410

FIGURE 9

Relationship between corrosion of zinc and deposition of SO_2



The corrosion rate of zinc as a function of SO_2 deposition. The dots represent readings at stations in the Federal Republic of Germany and in Great Britain.

109. The relationship between the corrosion for zinc and deposition of SO^2 in West Germany and the UK is shown in Figure 9 above. Not all materials are susceptible to deposition damage. Ordinary chromium-nickel-steels (stainless steels) are highly corrosion-resistant, even in a polluted urban atmosphere.[136] Any corrosion that occurs appears as slight discolouration or shallow pitting. Nevertheless, air pollutants can interfere with anti-rust painted steel by increasing the erosion of the coat of paint and by accelerating the corrosion of the underlying materials. Other materials eg paint on wood, plastics, paper, leather, textiles and plaster, also have their corrosion rates affected by sulphur pollutants or by their synergetic effects with other pollutants.

110. Ozone can react with many materials, resulting in damage. In particular, natural and some synthetic rubbers are vulnerable to ambient levels of ozone, resulting in the formation of cracks. Ozone has caused economic damage by inducing fading in certain textile dyes, this being promoted under conditions of high humidity and temperature. In addition, some types of paint are eroded by ozone, leading to a reduction in their useful life. Protection against ozone damage to materials takes the form of additions of anti-ozonant chemicals (in the case of rubber), or the development of more resistant formulations (in the case of dyes.)[137]

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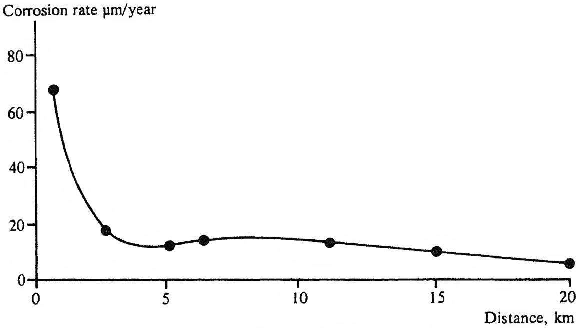
[136] Acidification Today and Tomorrow, Swedish Ministry of Agriculture, p108

[137] Lanting, R W. Material damage by photochemical oxidants. At state of the art review. OECD Workshop Gothenberg 1984

111. The importance of damage is illustrated by the fact that a galvanised steel plate with a coating 25µm thick, in an industrial environment would require painting after 3 years while in a rural area would last for 15-20 years before requiring painting.[138] Furthermore, damage is particularly bad near the source. Figure 10 below shows Swedish evidence of the relationship between the corrosion of carbon steel and distance from the pollutant source. The total corrosion effect by producing a film of moisture on the surface and by bringing hydrogen and sulphate ions which stimulate corrosion, but, against that, the rain washes away sulphates that have been deposited during dry periods.[139]

FIGURE 10

Corrosion of carbon steel at various distances from the emission source



Corrosion rate of carbon steel as a function of the distance from the emission source (a chimney in Kvarntorp, Sweden) over a ten year period.

112. Evidence of acid deposition damage to materials has been observed in various areas. In West Germany it has caused "structure bursting products" and the rusting of steel in steel-reinforced concrete constructions, such as Hamburg television tower, has occurred.[140] It has been argued that corrosion is occurring to an increasing extent. Moreover, galvanized steel in polluted areas is corroding at five times the rate in non-polluted areas.[141] Research in the USA, albeit in different atmospheric conditions, has also shown that acid deposition affects several materials including ceramics, glass, photographic materials and rubber.[142]

113. In the UK as long ago as 1968 the CEGB extended localised field studies of the corrosion of zinc coatings for transmission towers into a nationwide survey and it has undertaken other investigations into the effect on galvanised coating.[143] Despite such investigations there appears to be insufficient research into the effect of acid deposition upon materials and especially into means of protecting

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[138] ETSU para 412
[139] Acidification Today and Tomorrow, Swedish Ministry of Agriculture, p 104
[140] FRG Multilateral Conference paper, p 23
[141] OTA p 240
[142] ibid
[143] CEGB add ev p 2-3; Q40-1

such materials from further damage. **We recommend that the Government commission research on the effects of acid deposition on materials, and on means of protecting them, as a matter of urgency.**

F *Visibility degradation*

114. It may come as some surprise, given the undoubted visibility improvements after the Clean Air Act 1956 (an increase of 70 per cent in winter sunshine in central London), that we consider that the most widespread and readily observable effect of SO_2 and NO_x emissions is visibility degradation. We received evidence from Dr Derek Lee of Birkbeck College, London that such degradation is a fact, and we are aware of extensive research on this in the United States which has been the subject of a report to Congress by the Environmental Protection Agency in 1979.[144] Little work has been done here, and the Department of Energy's report makes no reference to it. This problem shows two features of wider significance. First, that reducing emissions would have a direct, beneficial, environmental effect. Visibility, which fell by 20-30 per cent between 1960 and 1973, as SO_2 emissions rose, has improved since as SO_2 emissions have fallen, and can be expected to improve directly if emissions are further reduced. Second, this is an example of environmental damage which is almost impossible to quantify for a cost-benefit analysis, but which cannot be ignored in setting out the harmful effects of emissions and the benefits which would follow from controls.

115. The mechanism by which SO_2 and NO_2 emissions come to degrade visibility is straightforward. Some 30% of all SO_2 emitted is oxidised to form sulphate. This consists of particles. Visibility reduction caused by urban or rural haze is controlled by fine particles. and these are most efficient at scattering light if their size is in the range of 0.1 to 2 microns. Sulphate and nitrate particles fall into this range: they are 0.1 to 1 microns. American monitoring of visibility has shown that at one location peaks of haziness between 1910-20 and 1940-50 coincided with peaks of fossil fuel burning. Research in North America has isolated the effects of sulphates and nitrates on visibility from effects resulting from natural phenomena such as fog, mist and blowing dust. In total, sulphates are estimated to contribute 50 per cent to visibility impairment in the eastern United States—70 per cent during summers.[145]

116. Dr Lee gave us evidence that, even allowing for different climatic conditions, similar effects had taken place in this country. Summer visibilities in southern England have fallen in urban and rural areas, partly due to imported sulphates. In rural areas that trend had continued since the 1950's, and Dr Lee related this closely to the long-range pollution problem of acid deposition. Summer sulphate and nitrate concentrations at one monitoring point in southern England have risen by 1.8 per cent and 4.5 per cent per annum since 1957.

117. Various consequences follow from improved visibility. The consequences fall into two groups. First, there are effects on transport, particularly aircraft. Second, there are aesthetic criteria: decreased perception of air pollution, the ability to see less polluted natural environments, improved clarity at night for astronomers, enhanced urban environments with improved visibility. Little work

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[144] AR 19; OTA, pp 244-54
[145] OTA, pp 244-54

has gone into the economic value of these. The poor quality of our rural monitoring network has undoubtedly contributed to our lack of knowledge. **We recommend that research on visibility degradation be commissioned.** To conclude, SO_2 and NO_2 emissions have a substantial effect, despite the Clean Air Act 1956, on visibility, and the reduction of those emissions is likely to have a direct benefit in improving visibility.

G *Health*

(a) *Acid rain is an increasing threat to Scandinavian water supplies*

118. In Sweden Dr Ulf Van Bromssen and Dr Dickson of the National Swedish Environmental Protection Board told us that acidification can have implications for human health. First, the leaching of copper and lead from water supply pipes by increasingly acidic water; secondly, the leaching from soil of heavy metals, such as cadmium and mercury, into water. Surface waters have, in southern Sweden, gradually become more acid, and it was expected that groundwater would follow in due course. There, over 50 per cent of drinking water comes from groundwater, and wells have shown a fall in pH of 1.5 during springmelts. Whilst as yet no significant decrease in the pH of community water supplies had occurred, heavy metal contents were rising in some areas, as too was sulphur. The rise in acidity has meant that corrosion of copper piping is worsening. pH had fallen to less than 5 in 7 per cent of drilled wells and 16 per cent of dry wells in western Sweden. The value put on copper corrosion was, based on insurance data, some 150 mill SKr per annum. Evidence was cited of copper leaching having caused diarrhoea in small babies, and this has been confirmed by UNECE.[146]

119. American evidence supports the Swedish case. Evidence has been found of lead in rural drinking supplies resulting in levels in the blood above safety limits. In the Adirondacks, the worst affected lakes area, elevated copper levels have been monitored in drinking water.[147]

(b) *Acid rain causes increased mercury levels in fish, which pose some threat to human health*

120. Dr Dickson gave us evidence on mercury. In Southern Sweden mercury levels in fish, particularly predatory fish at the end of the aquatic food chain, were distinctly higher the more acid lakes were. The catching for sale of pike for human consumption has been prohibited in a very large number of lakes in consequence. Dr Dickson estimated that between a quarter and a half of Southern Sweden's 20,000 lakes fall within this category due to mercury levels. Liming was no solution, since it merely increased metal content in lake sediment. He considered such mercury levels in pike posed a particular danger to human foetuses, although none to adults or children. The same danger does not exist in respect of trout.

(c) *Are there similar risks in the UK?*

121. We put these points to DOE's Chief Scientist, and he acknowledged he was unaware of this evidence. Extensive lead and copper piping exists here, and limited work has been done. In Galloway and elsewhere water supplies are now limed but no study has been made to discover whether it is safe to eat local pike. He suggested mercury levels might be a consequence of old industrial sources.[148]

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[146] ETSU, pp 100-1
[147] OTA, pp 260-1
[148] Q220-6

However, Professor Rodhe of the Department of Meteorology at the University of Stockholm told us that in Sweden these remain in the soil after those sources are closed, and are leached out by acidic water. In addition, a certain proportion of mercury pollution is transmitted through the air. We received no evidence to suggest that there is any cause for similar concern in this country over mercury.

(d) *Effects on respiratory disorders*

122. A further type of health effect was cited to us by the German Minister of the Interior, Herr Spranger. Recently instituted paediatric research programmes had suggested that levels of asthma, allergy, hay fever, etc, were rising, and that air pollution might be the cause. Researchers in the US at Brookhaven National Laboratory, doing work commissioned by the Office of Technology, have confirmed serious health effects from sulphate particles in the atmosphere.

(e) *Conclusion*

123. Two things are undisputed: first, that high concentrations of SO_2 and NO_x as particulates in the atmosphere can kill. Second, research has not gone on in this country into the health effects of lower concentrations of particulate sulphates and nitrates in the atmosphere. World Health Organisation research has shown that these particles in the atmosphere only affect people already suffering from respiratory disorders, bronchitis and asthma.[149] However, American research goes a little further by suggesting that the combination of sulphates with other associated particles (metallic ions, nitrates from NO_x emissions, fine soot) are generally injurious to health. High concentrations could cause increased breathing rates and altered lung functions in those at risk with pre-existing heart or lung disease and asthmatics. Acid sulphates also render lung tissues more susceptible to the carcinogenic effects of polycyclic organic matter. The Office of Technology Assessment concluded that to reduce SO_2 levels by 30 per cent from 1978 levels would reduce annual deaths from US pollutant emissions by no less than 10,000 people.[150] Similar conclusions were drawn by the Swedish Government Committee on Automotive Air Pollution.[151]

124. We consider that the almost total absence of research in this field is to be deprecated. Such evidence as is available from the US and Sweden suggests there is a human health risk which may well be worsening. The US and Swedish evidence is difficult to ignore in the absence of work here. It demonstrates that in those countries at least there is cause for concern. **We recommend that the Government should commission research in this country on all aspects of risk to human health to which US, Swedish and German research has drawn attention, with a view to establishing whether similar risks exist in this country.**

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[149] ETSU, p 99

[150] OTA, pp 255-9

[151] Motor Vehicles and Clean Air, pp 17, 87-117

III. ACID RAIN: POLLUTERS AND SUFFERERS

125. We have set out the effects of acid rain on the environment,and the importance of SO_2 and NO_x. In this section we analyse the contributions made by different countries to the problem. We have concluded that to reduce depositions would have beneficial effects. At the end of this section we therefore address the question of whether to reduce emissions would reduce depositions. We then set out the sources of SO_2 and NO_x in this country, in order to set a background against which various control options can be considered.

1 The Emission and deposition of SO_2 and NO_x

(a) *Who emits SO_2*

126. The United Kingdom is the largest single emitter of SO_2 in the whole of Europe with the exception of the Soviet Union, which, because of its position and land mass, exports only 4 per cent of its emissions.

USSR	16,200,000 tons emitted
UK	5,120,000 tons emitted
Italy	4,400,000 tons emitted
E. Germany	4,000,000 tons emitted
W. Germany	3,620,000 tons emitted
France	3,600,000 tons emitted[152]

These figures conceal the fact that the United Kingdom's figures have reduced by 37 per cent between 1970 and 1984. Despite this, the United Kingdom remains, with the exception of the USSR, top of the list. Department of Energy forecasts suggest that this lead will dramatically increase.[153] Between 1980 and 1990 United Kingdom emissions are projected to fall by less than 5 per cent: West German emissions will fall by 60 per cent by 1988, and many other West European countries by 30 per cent by 1993. The Department of Energy's Report on acid rain said that with increased industrial growth, emissions might actually rise.[154]

(b) *UK depositions in other countries*

127. Turning to the amounts deposited, some 80 per cent of the sulphur deposited in this country is from our own emissions, and this constitutes 1,620,000 tons. We therefore export most of our emissions—some 70 per cent. Over half falls in the sea, harmlessly. That leaves 28 per cent of our emissions deposited in other countries, principally Scandinavia (due to weather patterns). Many countries deposit a greater proportion of their emissions than 28 per cent in other countries. However, in terms of actual quantities, the United Kingdom is second only to West Germany in Western Europe in the amount of sulphur it deposits in other countries.[155] Atmospheric scientists in Norway told us that the UK deposited twice as much in Norway as any other country, including Norway itself. In Sweden we are in the second largest source of deposited sulphur after Sweden itself, and will be the largest by 1990 when a Swedish emissions control programme has worked through.[156] The United Kingdom is therefore the worst polluter of other countries in Western Europe, despite having ratified the

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[152] Ev, p 64

[153] Ev, p 61

[154] ETSU p 9

[155] Ev, p 64; Q182-3 189-95

[156] Acidification Today and Tomorrow, Swedish Ministry of Agriculture

Convention on Long-Range Trans-boundary Pollution. The bulk of the pollutants—two thirds—come from power stations, and given the use of tall stacks to disperse these pollutants, it is likely that an even higher proportion of our pollutants we deposit in other countries comes from CEGB power stations.[157]

(c) *NO_x emissions*

128. A similar picture emerges for NO_x. 1978 OECD figures show that only West Germany produces more NO_x than this country.[158] NO_x contributes one third of acid rain falling in Scandinavia, according to their expert scientists. Whilst West Germany has acted to control its NO_x emissions, the Department of Energy has projected that NO_x emissions in the United Kingdom will rise by 10 per cent by 2010 and suggested that figures for NO_x emissions from motor vehicles in the UK may be too low by some 15 per cent.[159].

(d) *Atmospheric processes: will reducing emissions reduce depositions?*

129. Much work has been done to assess the effects on depositions of reducing emissions. We have produced evidence to show that reducing depositions will reverse some damage, slow down other damage, and reduce the threat of new or further damage both to our own and the Scandinavian environment. A key question is therefore whether reducing emissions will reduce depositions. So far only limited work has been done on atmospheric modelling but DOE has instituted some research on that this year.[160] Nevertheless, it is self-evident that if less SO_2 and NO_x are produced, then less will be deposited. That is of itself desirable in principle. The NERC confirmed this: controls would reverse the acidification process, although not necessarily immediately.[161]

130. Whether there is a linear relationship between emissions and depositions is more problematic. First, given that 20 per cent of sulphur in the atmosphere in northern Europe is not from man-made pollution, but is from natural sources such as volcanic eruptions, there will not, in percentage terms, be a 1:1 relationship between reduced emissions and reduced depositions. Second, chemical atmospheric processes, which are not all scientifically understood, may not be turning given quantities of emissions into equal quantities of depositions. However, we received evidence from Professor Rodhe in Sweden that a linear relationship between emissions and depositions could be demonstrated. Figure 11 on page lii shows that a definite decline in depositions in Scandinavia has been observed since 1975, which correlates closely to the line of a graph showing a fall in SO_2 emissions since the 1970-4 period in Western Europe. After modelling the sources of Scandinavian emissions and the decline in those emissions, he projected a 15 per cent fall in depositions, which is roughly what *has* been observed. Other scientists said that in southern Sweden a fall in depositions had been detected which could be correlated with known falls in emissions by some of the countries, including Sweden itself, responsible for Swedish depositions. At Birkenes, in southern Norway, a rise in the pH of rainfall since 1979 had been detected which reflected reductions in emissions.

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[157] Ev, p 60; see the table on page liii.

[158] Ev, p 65

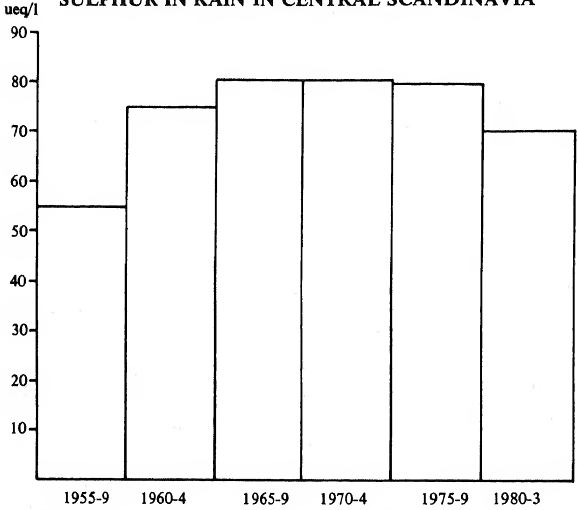
[159] ETSU, p 169

[160] See AR 25

[161] Q530, Q556

FIGURE 11

SULPHUR IN RAIN IN CENTRAL SCANDINAVIA



2 *Sources of SO_2 and NO_x in this country*

(i) *Emitters of SO_2 and NO_x*

131. The tables on the next two pages show that the major emitters of sulphur dioxide in this country, by a considerable margin, are non-nuclear power stations, and that there has been no significant reduction in CEGB emissions during the period when total UK emissions fell. If action is to be taken to control the volume of UK emissions, it could therefore be focussed largely on this single source. A similar pattern is evident in West Germany, which has imposed reductions of 85 per cent in its power stations over 300MW. For NO_x, the picture is also one in which the major source is the CEGB, and again no decline is evident.[162] With regard to SO_2 the decline in emissions can be attributed partly to the recession, partly to the change in the nature of our industries and partly to a switch from fuel oil and coal to natural gas for private industrial and domestic use. With regard to NO_x, there has been little overall decline. However, emissions by private industry have halved since 1970, whilst emissions of NO_x from motor vehicles have substantially increased. As we have shown, the figures for levels in this country are suspect as being too low.[163]

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[162] ETSU, pp 167-79

[163] Q648, Q676

Table 1: Sulphur dioxide: estimated emission from fuel combustion: by type of consumer and fuel[1]

(a) By type of consumer

Million tonnes

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	*Percentage of total in 1982*
Domestic	0.37	0.36	0.35	0.30	0.28	0.29	0.26	0.26	0.22	0.21	0.20	*5*
Commercial/ public service[2]	0.31	0.29	0.26	0.24	0.24	0.24	0.23	0.24	0.20	0.18	0.17	*4*
Power stations	2.87	3.02	2.78	2.82	2.69	2.74	2.81	3.10	2.87	2.71	2.65	*66*
Refineries	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	*5*
Other industry[3]	1.75	1.77	1.59	1.44	1.42	1.37	1.36	1.38	1.05	0.84	0.76	*19*
Rail transport	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	*<1*
Road transport	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.05	*1*
All consumers	5.64	5.80	5.35	5.13	4.98	4.98	5.02	5.34	4.67	4.23	4.04	*100*

(b) By type of fuel

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	*Percentage of total in 1982*
Coal	2.65	2.89	2.56	2.68	2.74	2.79	2.77	3.10	3.02	2.91	2.75	*68*
Solid smokeless fuel	0.18	0.17	0.16	0.15	0.13	0.13	0.13	0.13	0.10	0.10	0.10	*2*
Petroleum:												
Motor spirit	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.02	*<1*
Derv	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	*1*
Gas oil	0.20	0.20	0.17	0.17	0.16	0.14	0.14	0.14	0.09	0.07	0.07	*2*
Fuel oil	2.29	2.20	2.10	1.82	1.61	1.58	1.64	1.62	1.13	0.86	0.86	*21*
Refinery fuel	0.26	0.29	0.30	0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	*5*
All fuels	5.64	5.80	5.35	5.13	4.98	4.98	5.02	5.34	4.67	4.23	4.04	*100*

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[1] Excludes emissions from chemical and other processes, which probably amount to a few per cent of emissions from fuel combustion.

[2] Includes miscellaneous consumers.

[3] Excludes power stations and refineries; includes agriculture.

Source: *Warren Spring Laboratory, Department of Trade and Industry*

Table 2: Nitrogen oxides, estimated emissions by source

Nitrogen oxides[2] Thousand tonnes

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	*Percentage of total in 1982*
Domestic	51	53	53	51	50	52	52	56	52	52	51	*3*
Commercial and Industrial	470	486	449	408	419	415	405	417	338	318	309	*19*
Power stations	731	808	722	760	770	793	806	876	851	818	769	*46*
Incineration and agricultural burning	8	8	8	10	12	12	12	12	12	12	12	*1*
Road vehicles												
petrol engined	262	279	272	266	279	286	303	308	316	309	318	*19*
diesel engined	158	170	166	162	168	171	176	182	176	167	172	*10*
Railways	48	50	47	44	41	42	42	41	40	39	35	*2*
All emissions	1,728	1,854	1,716	1,700	1,739	1,771	1,796	1,893	1,785	1,714	1,666	*100*

Source: *Warren Spring Laboratory, Department of Trade and Industry*

(ii) *How can further reductions in UK emissions be achieved?*

132. The Government at the Munich Conference in June 1984 and in evidence to us has said it will act substantially to reduce SO_2 and NO_x emissions further. The fall to date has been principally from industry, that is from sources unlikely to produce further significant reductions. Indeed, both Mr Waldegrave and the Department of Energy, in its ETSU Report, warned there may be a rise as industrial recession eases.[164] Nevertheless, the Government has committed itself to further "substantial" reductions in emissions. To achieve them, the fall can only come in power station emissions, which have hardly fallen at all since 1970. With no major stations nearing the end of their lifespan, there are no short and medium term prospects for reducing emissions by installing new technology replacement stations. Therefore the most practical way of cutting our SO_2 emissions further is to add new technology to existing stations. This was confirmed by the Minister, Mr Waldegrave.[165]

(iii) *The need for rural monitoring*

133. Perhaps the most significant factor in the sulphur budget and its effect on our own environment is the level of SO_2 depositions and the pH of rainfall in rural and urban areas. Existing monitoring of a large number of urban sites shows winter concentrations of SO_2 have fallen since the early 1960's except for a rise recorded in the last published data year, 1981/82.[166] However, the tall stacks policy might be expected to have increased rural depositions. This is because transportation in the atmosphere over longer distances increases the chances of gaseous SO_2 and NO_x being converted to sulphates and nitrates which together are the main contributors, in northern Britain and elsewhere, to the excess acidity of acid rain.[167]

134. In contrast with monitoring in urban areas, the Warren Spring Laboratory Report shows that extensive parts of rural Britain are not monitored for SO_2, NO_x, rainfall pH or ozone. Indeed, Warren Spring Laboratory runs only three NO_x monitoring stations, two in the South East and one in East Anglia.[168] Data are not availabe to show if rural levels of pollution have increased since the introduction of the tall stacks policy. Annual averages are not available for most of the country, let alone the daily or weekly patterns that would show the spikes of acidity which are of significance to the environment, or ozone levels which are crucial to crop and tree damage, particularly in the latter case at high altitude. CEGB figures for ozone levels are based on monitoring at low altitude, from which, in evidence to us, they extrapolated to high altitudes.[169] Concern was expressed to us by many scientists, including the Institute of Terrestrial Ecology.[170] **We recommend that a rural network of monitoring stations at different altitudes over the whole country be set up as a matter of urgency.**

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[164] ETSU, p 9; Q651
[165] Q651
[166] Digest of Environmental Statistics, 1983, p 13
[167] AR 48, p 6
[168] Q176
[169] Q113
[170] AR 48

IV. EMISSION CONTROLS

135. We have demonstrated that a wide range of environmental damage results from SO_2, NO_x and ozone pollution. We have shown there is a substantial risk of further damage, here and in the rest of Europe. We believe controls would reduce or eliminate the risk of more damage, slow down existing rates of some damage, and allow the reversal of damage to occur. We now consider how these controls could be achieved—the technology involved for each major emission source. We conclude that there are no insurmountable technical obstacles to controls. We then show the cost of different levels of controls, before assessing how that cost should be balanced against environmental benefits.

1 EMISSION CONTROL TECHNOLOGY

(a) *SULPHUR DIOXIDE EMISSIONS BY INDUSTRY AND POWER STATIONS*

136. We have already warmly welcomed the Government's commitment to further reductions in SO_2 emissions. We have noted however, that the scope for further significant reductions without reducing emissions from existing power stations is very limited. Sulphur emissions can be reduced in four ways.

(i) *Use of low sulphur fuels*

137. The sulphur content of fossil fuels can range from 0.5 per cent up to over 5 per cent. In West Germany, there are extensive resources of low (<1 per cent) sulphur fuels. Swedish control legislation requires that no more SO_2 should be emitted than would be by the combustion of coal with a sulphur content of 0.65 per cent. A district heating station we visited in Sweden had reduced emissions to 0.3 per cent. UK coals average 1.6 per cent, those supplied to power stations are at that level, and there are virtually no low sulphur coals available in sufficient quantities for power generation.[171] Unlike West Germany reductions in emissions by small, often old industrial plants cannot be achieved by the use of low sulphur fuels unless that fuel is imported, as is happening in Sweden.[172]

(ii) *Removing sulphur before use (coal washing)*

138. UK coals contain two forms of sulphur, organic and pyritic. Only the pyritic form can be removed before burning. A maximum of 8 per cent of the sulphur present in average UK coals could be removed from coal by washing.[173] Some two-thirds is already washed: the remainder is considered too fine to be economically washed, and so is blended in a mix with washed coal. The National Coal Board considered that for geological and technical reasons "no amount of additional investment seems to yield any improvement in the sulphur".[174] The additional cost of extracting the remaining sulphur from that coal would be £1.80 per ton of coal used by the CEGB.[175] The cost would be, on average, £850 per tonne of sulphur removed if coal from 24 pits with high sulphur levels were washed, more if total washing were extended to all power station coals. By comparison, CEGB advised us that flue gas desulphurisation would cost about £550 per tonne of sulphur removed.[176] We are satisfied at present that there is no economic scope for further coal-washing, and that this should not form part of a programme to reduce SO_2 emissions.

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[171] Q598
[172] The Swedish Coal-Health-Environment Project
[173] Ev, p 9
[174] Q609
[175] Q605-6
[176] Ev, p 10

139. The sulphur content of heavy fuel oils could be reduced by residual desulphurisation or by the choice of low sulphur crudes. The capital costs of removing one tonne of SO_2 from heavy fuel oils are in the range of £680-£1,585 with annual operating costs of £300-£641 (including an annual capital charge). "Estimates for 1990 indicate that the combined oil-burning sectors will by then have achieved a 42 per cent reduction in SO_2 emissions from 1980"[177] but as a result of the business downturn and fuel switching etc, emissions are already 30 per cent down. The CBI concludes that the introduction of residual desuphurisation by the oil industry "would be costly and have little impact on overall UK emissions". Since the oil industry has 17 refineries, and possibly eight individual plants above the 50MW level it would be costly to retrofit them all.

(iii) *Removing sulphur during combustion of coal: pressurised fluidised bed combustion*

140. In this technique limestone and/or lime are mixed with coal dust and fed into a combustion chamber with a perforated bottom. Air is blown through the bed, causing the particles to float freely and to become fluidised. Combustion can be made to take place under pressure: it occurs at about 850°C without visible flames. Among the advantages of this technology are that the sulphur is captured by limestone in the bed, reducing SO_2 emissions by 90 per cent, and that the low temperature of the combustion keeps down the formation of NO_x. Variations in the quality of the fuel are relatively unimportant and the CEGB advise that generation efficiency can be increased to 40 per cent.[178] American studies indicate potential generating cost advantages of the order of 13 per cent compared with new conventional plant fitted with FGD.[179] The NCB has an advanced £25 million research programe underway, and it would be commercially available in five to seven years' time, and we were assured that additional expenditure would shorten that timescale considerably.

141. Mr. MacGregor of the NCB told us that it was very promising because "it has, in addition to the improvement in terms of SO_2 and NO_x, also the added advantage of having potential for improving the efficiency of the combustion systems, which means that we might end up with environmental enhancement systems that are reasonably self-financing".[180] PFBC therefore offers an exciting prospect. In the long-term, emissions controls of very high levels will not leave coal-burning at a disadvantage to nuclear power. The "best practical means" required by the Industrial Air Pollution Inspectorate will therefore favour, on environmental *and* economic grounds, high levels of emission controls. The Industrial Air Pollution Inspectorate has said it would expect SO_2 controls on new coal-fired power stations. The advantages are such that **we recommend that greater impetus be given to the perfection of this technology for commercial use.**

(iv) *Sulphur removal from combustion products*

142. Until PFBCs are ready, desulphurisation of combustion gases is the only

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[177] Ev, p 190
[178] Ev, p 10
[179] Ev, p 277
[180] Q619

practical way to reduce SO_2 emissions from existing power stations and industrial plant, but it is not cheap. Since 1909 power stations have been required to leave space for gas desulphurisation systems, but no direction has been given to install them. Systems have been brought into use abroad.

143. Flue gas desulphurisation is effected by inserting a removal process between the combusiton chambers and the waste chimney and bringing the waste gases into contact with wet or dry alkali to absorb the SO_2. The use of limestone in a water suspension produces a limestone slurry or gypsum, which might be of commercial value. The West German programme, we were told, will produce enough gypsum to meet all current needs. Indications in this country are that the cement and construction industries could assimilate most or all of the products, and that a substantial land disposal problem need not therefore result from controls.

144. There is a system of dry flue gas desulphurisation. This produces a dry product, has lower energy and water requirements, and costs less to install than the wet systems used in West Germany. It would therefore offer potential for small output stations. The British Aggregate Construction Materials Industries advised us that the industry could produce the quantities of limestone, lime or chalk likely to be required.[181]

145. Wet FGD systems can achieve 90 per cent reduction levels. Existing technology is largely Japanese, American and West German. NEI International Combustion Ltd. has licensing arrangements.[182] Lodge-Cotterel[183] has a fully operational desulphurisation pilot plant in this country. The latter was refused permission by the CEGB to install a large pilot plant on a power station. This illustrates a major concern we discovered during our inquiry. The CEGB spends £1½ million on the environmental effects of acid rain. It is spending less than £200,000 of FGD research, mainly on paper assessments of foreign systems.[184] If the Government therefore sought British technology for FGD, the CEGB would have little to offer, and appears to have actually obstructed work by British companies. We find this hard to understand. We have noted earlier that any further reduction in SO_2 emissions would have to rely heavily on retrofitting existing power stations. The lack of work or support by CEGB for British development will either lengthen the timescale or force the use of foreign technology. We find this regrettable. **We recommend that the necessary resources be devoted to FGD by the CEGB, not least in order to reduce its cost.**

(v) *Summary*

146. Technology exists to achieve SO_2 emissions reductions of 90 per cent or more. A considerable market has opened in Europe for emission control technology, both through PFBC and DFGD and the provision of fluidised-bed boilers. **We recommend that further encouragement be given to the development of British technology both through NCB and CEGB research and through grants towards development costs by the Department of Trade and Industry.**[185]

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[181] AR 2
[182] AR 22
[183] AR 9
[184] Ev, pp 7-8
[185] AR 27

(b) *NO_x EMISSIONS*

147. In this section we consider the technology to remove or reduce NO_x emissions from stationary sources and from motor vehicles. Levels of NO_x emissions are not significantly declining, and motor vehicles are becoming increasingly significant emitters, both in this country and in Europe.

(i) *Stationary sources*

(a) *Low NO_x burners*

148. Various types of burners exist for reducing the emission of NO_x. The CEGB said that special burners could achieve a 30-40 per cent reduction of NO_x, but considered this to be a maximum. There are no additional operating costs, and capital costs are minimal.[186] We were interested to receive evidence, from Foster Wheeler Power Products Ltd,[187] that they had devised a low NO_x burner capable of achieving a 60 per cent reduction in emissions.

(b) *Flue gas denitrification*

149. Like flue gas desulphurisation, this system involves the reduction of NO_x by effectively filtering emissions or flue gases. Reductions of 80-90 per cent follow, but the cost is similar to that of flue gas desulphurisation.

(ii) *Motor vehicles*

(a) *Introduction*

150. In this section we consider the two ways available to reduce NO_x emissions by motor vehicles—catalysts and lean-burn engines. We would, by way of introduction, say how appalled we were at the standard of evidence received from motor car companies. They showed an almost total lack of awareness of the roles of NO_x and hydrocarbons in producing ozone, despite this having been well documented in the United States and elsewhere. SMMT made no mention of ozone at all. BL Technology interpreted acid rain in the narrowest possible sense of SO_2 and Ford largely ignored ozone, as did the Talbot Motor Company Ltd.[188] Most argued that because motor vehicle emissions of NO_x contributed some 7-10 per cent of total acidity in wet and dry deposition, this was insignificant. The West German Goverment is convinced of the significance of NO_x and ozone to its forest damage, and scientists agree these have an important role. We believe a reduction in emissions on NO_x and hydrocarbons by motor vehicles is desirable, first, because of the contribution of these emissions to acid precipitation, but also, more significantly, because of their role in producing ozone.

(b) *Catalysts*

151. Two types of catalyst systems exist. "Lead-tolerant" catalysts are designed to work with leaded fuels. The technology is not yet fully developed. Consequently they "are incapable of yielding any control over nitrogen oxides emissions".[189] The second type are catalysts for use with lead-free petrol. These have formed the basis of emissions control systems in the USA and Japan for nearly a decade. They are known as three-way catalysts and function to reduce NO_x and other emissions. According to the SMMT they have several

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[186] Q25
[187] AR 21
[188] Ev, pp 160-1
[189] AR 1 Appendix 3

disadvantages: effective operation is only obtained when exhaust gases reach temperatures of 600-800° Centigrade,[190] for instance on long motorway runs; electronic controls are required to ensure that the correct fuel: air ratio is maintained;[191] fuel consumption is increased by 10 per cent;[192] they cost £450-500 each, irrespective of car size and so the initial cost burden would fall disproportionately on the purchasers of cheaper cars;[193] that replacement catalysts would cost £200;[194] furthermore they require expensive metals found in few places,[195] and their life-span would only be 3-4 years[196]; they are "poisoned" if leaded petrol is used.[197] We were also given evidence by Ford Motor Co. that while three-way catalysts work in American cities, European urban stop-start motoring is quite different to that found in the USA.[198]

152. These statements were challenged by a major catalyst producer: Johnson Matthey Chemicals Ltd.[199] They argued that tests had shown that catalysts operated in the 300-980°C temperature range, that there should be no need to use electronic controls to maintain temperatures, that they would not induce power losses of 10 per cent (more likely under 2 per cent), that the cost of catalytic converters is only £50 to the manufacturer of the vehicle and that they are designed to meet emission standards for 50,000 miles and, "provided it is operated in accordance with the manufacturer's instructions, will last and work for the life of the car."[200] Nevertheless catalysts can remove 97 per cent of NO_x and 90 per cent of hydrocarbon emissions.

(c) *Lean burn Engines*

153. Lean-burn engines are the alternative to catalysts. In these, virtually total fuel combustion is attained by mixing with relatively large quantities of turbulent air: a ratio of between 1:18 and 1:22. Such engines, due to be produced by 1986/87, would add £50-100 to the cost of a motor vehicle.[201] They have the additional advantage of fuel economy improvements over and above conventional engines of up to 15 per cent.[203]

(d) *Controls on motor-vehicles: best practicable means*

154. The AA argued that the introduction of three-way catalysts would be very expensive while the effect on the "acid rain burden" would be only about a one per cent reduction.[204] The AA suggested therefore that "for an additional cost of £50 to £80 per new car, instead of £350 to £550 which the fitting of three-way catalysts implies, it may be possible to achieve between one half to two thirds of the potential exhaust emission reduction claimed for by the protagonists of the three-way catalyst solution".[205] It is our belief that, in the present state of technology, lean-burn engines represent the best practicable means of reducing NO_x emissions. Provision can also be made for reducing hydrocarbons. **We recommend that any programme to limit NO_x and hydrocarbons emissions from motor vehicles should be based on lean-burn technology.**

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[190] Ev, p 149
[191] Q367
[192] Ev, p 153
[193] Q367
[194] Q369
[195] Q402
[196] Ev, p 154
[197] Ev, p 153
[198] ibid
[199] AR 1
[200] ibid, addit. evid.
[201] Ev, p 148 Q384
[202] Ev, p 148; Q384
[203] Q381-2 and p 148
[204] Ev, p 167
[205] Ev, p 168

2 THE COST OF CONTROLS

155. Two main approaches to imposing controls have been prepared, the EEC's and West Germany's. The levels of controls called for by the EEC draft directive COM (83) 704 are as follows:

Emission limit values of sulphur dioxide, dust and oxides of nitrogen (in mg/m^3 of waste gases under standard conditions

Pollutant Type of fuel	Sulphur Dioxide(1)		Dust	Oxides of nitrogen(2)	
	As from 1.1.1985	After 31.12.1995		As from 1.1.1985	After 31.12.1995
Solid	≤ 400 as a rule	≤ 250 as a rule	≤ 50	≤ 800 as a rule (≤ 1,300 for pulverized coal-firing with extraction of fused ash)	≤ 400 as a rule (≤ 800 for pulverized coal-firing with extraction of fused ash)
	(≤ 2,000 for grate-firing or pulverized coal-firing where the output is less than 300 MW)				
Liquid	≤ 400 as a rule	≤ 250 as a rule	≤ 50	≤ 450	≤ 220
	(≤ 1,700 for plants where the output is less than 300 MW)				
Gaseous	≤ 35 as a rule (≤ 100 for coke oven gas) (≤ 5 for liquefied gas)		≤ 5 as a rule (≤ 10 for blast furnace gas) (≤ 100 for gases produced by the steel industry which can be used in industry)	≤ 350	≤ 180

(1) Account should be taken of the proportion of sulphur trioxide in the waste gas.

(2) Nitrogen dioxide need not be measured continuously if it accounts for less than 5 per cent of total emissions of oxides of nitrogen. The proportion of nitrogen dioxide should then simply be calculated.

These emission limit values must be consistent with the draft directive's requirement of a 60 per cent reduction in SO_2 emission levels, 40 per cent in NO_x and 40 per cent of particulates from large combustion plants (over 50MW), taking 1980 as the base year. This would affect at least 31 CEGB power stations, 14 being over 1000 MW.

156. The West German Government has imposed more severe controls. All major power stations are to be required to reduce sulphur emissions by 85 per cent within four years of the imposition of controls. Constant emission limits have also been imposed which are similar to those proposed by the European Commission. Smaller stations are to meet the same targets by 1993. Similar provisions, also differing between large and small plants have been applied to all industry. NO_x reductions of 60 per cent are expected. The cost will be, we were told in West Germany, up to 10 per cent on consumer electricity prices. Lean-burn technology for motor cars will be mandatory from 1986, as will, as presently planned, lead-free petrol. Catalysts are not, however, yet required. The West German programme goes, therefore, further than that of the EEC in a shorter timescale.

The need to control motor cars, given their role in forest damage, is particularly crucial. The implementation of the programme for power stations is assisted by the fact that new stations continue to be built and others decommissioned. Control technology can therefore be an integral part of the station. Also, combined heat and power stations are being rapidly built. Some 20 per cent of stations will, therefore, not be retrofitted but will close down, because to add control technology would be too expensive.

157. If controls are imposed there would be two forms of cost:

(a) the *direct costs* incurred by those producers of emissions who are required to fit control technology. This includes both initial capital and subsequent manning costs.

(b) the *indirect costs* in the form of higher prices faced by the customers of those firms which introduce control technology. Electricity costs are the main single indirect cost which would be incurred.

(a) *Direct costs*

(i) flue gas desulphurisation

158. The CEGB told the Committee that to include flue gas desulphurisation in a new 2000 Megawatt power station would involve capital costs of £60–125 million.[206] In addition, running costs of £24–30 million per annum would be incurred. These figures represent increases in costs over non-controlled power stations of 15 per cent on capital and 9–15 per cent on running costs.[207] However, as we have shown, in order to meet the timescale and level of reductions in emissions called for by the EEC Draft Directive COM(83) 704, retrofitting of power stations would be required. This would involve capital costs ranging from £39–160 million per power station plus running costs ranging from £15.2–34.6 million each per annum at 1983 prices.[208] These costs are calculated on the basis of using one of three types of flue gas desulphurisation—Wellman-Lord, Limestone Gypsum or sea-water washing (at one coastal coal fired power station).

159. To meet the requirements of the EEC Draft Directive, would require up to 12 power stations to be retrofitted.[209] The overall capital cost would be £1,432 million at 1983 prices "with an additional £560 million if it were necessary to replace the output capacity lost through the use of the FGD system".[210] The loss in efficiency caused by retrofitting would range from 0.9–1.4 per cent and the additional cost required to replace output capacity lost represents an increase of 39.2 per cent on the overall capital costs, taking the possible total to £1,990 million. This figure compares with the total cost of implementing the 1956 and 1968 Clean Air Acts over the 26 years from 1958/59 to 1983–84 of £757 million at 1983 prices.[211]

160. However, the financial impact of a programme of FGD would not occur at one time. Figure 12 on page lxiii charts the development of the annual costs of

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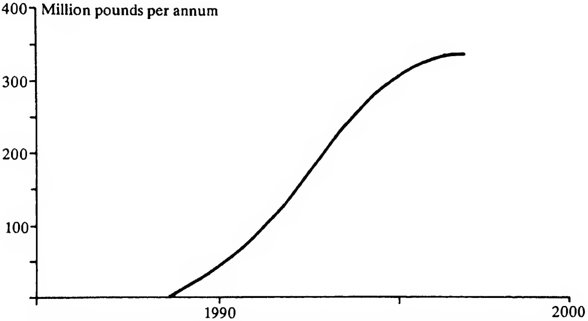
[206] Ev, p 10
[207] Q52
[208] Appendix 2 of CEGB supplementary evidence
[209] Ev, p 12
[210] CEGB supp. evidence p 1
[211] Ev, pp 319–20

financing and operating a programme and shows that the peak in total annual costs of £350 million would occur in the late 1990's. Between 1992 and 1997 annual operating costs of the FGD programme would increase from approximately £80 to £330 million per annum. For the first full-year of operation the running cost to the CEGB of retrofitting the 12 largest power stations would be £338 million. According to N Heighton of Beijer Institute[212] "an investment programme to introduce FGD at existing and new large coal-fired power stations would result in capital and operating expenditure of up to £450 million per annum (1984 prices)." A further critical point is that in the long-term, as existing stations were taken out of service and replaced by new stations using more efficient fluidised bed combustion, the costs of controls would actually *fall* to below zero in comparison with conventional stations fitted with FGD.

FIGURE 12

Annual cost of financing and operating a programme of flue gas desulphurisation at existing power stations to achieve by 1995 a 60% reduction of CEGB SO_2 emissions below 1980 levels.



NB: Costs include capital charges and running costs including replacement of peak power output loss and energy loss.

Source: CEGB additional written evidence

(ii) Low NO_x burners in power stations

161. Additional costs for reducing NO_x emissions by 30-40 per cent would be incurred. It is difficult to say what would be the costs of meeting the proposed EEC requirements since, according to the CEGB, it "would be more problematical; at this stage we do not know whether it is possible to retrofit low NO_x burners to the majority of our boilers".[213] However, we have had evidence that 60 per cent reductions could be obtained in certain areas.

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[212] AR 65
[213] Ev, p 12

(iii) Costs to industry

162. The CBI advised the Committee that its members would be unable to cope with any increase in operating costs.[214] The CEGB estimated that industrial costs to consumers would go up by about 6 per cent, Mr Heighton of the Beijer Institute suggested 2.9 per cent%.[215] The CBI talked generally of 5–10 per cent. The difference in figures was described by the CBI as "moving goal-posts".[216] The CBI appeared to have taken no account of the period over which the extra cost would take effect.[217] Nor could it offer any advice on the different costs of the three major options for control, the 30 per cent Club, the EEC directive, and West German levels of controls.[218] No figure on the effect on competitiveness, given that other European countries would also be imposing controls, was available. The CBI concluded that controls would affect the competitiveness of "enough plants which will go out of business."[219]

163. We are disturbed that the CBI's response to a serious debate on acid rain, which must take full account of the costs to industry in assessing whether benefits are commensurate with costs, is to have done no work of any sophistication on costs to industry. Its opposition to controls appears instinctive rather than based upon a convincing analysis of costs, and as a result the CBI has at present little to offer policy-makers in coming to their conclusions. This is a matter of regret to us.

164. Direct costs will also be incurred by other industries which generate emissions. The CBI claimed that the cost of reducing SO_2 emissions ranged from £65 to £200 per kW varying with the plant thermal output.[220] As the plant thermal output increases so the cost of emission control per kW reduces. For plants with a thermal capacity from 50–300 MW the capital cost would be between £10–39 million per plant. The exact costs are difficult to calculate since "the impact of direct reduction targets varies from industry to industry, from company to company".[221]

165. To illustrate the cost of meeting the EEC Draft Directive the CBI cited three examples. The textile industry has eight sites with multiple boiler units and varying capacities: the reduction of SO_2 emissions by only 30 per cent would involve a capital cost of £25 million and annual operating costs of £18 million—"burdens too high for the industry to accept and remain competitive".[222] The chemical industry also has 80 plants of over 50 MW thermal output. Similarly the glass industry needs high temperatures to operate and is therefore a major NO_x producer. It has about 10 plants that would require controls.[223]

166. Another important emitter is the cement industry. Blue Circle Industries estimate that less than 25 per cent of the total sulphur entering its production process escapes into the atmosphere. Since the company uses only 2.8 per cent of the CEGB's annual coal use it is argued that "relatively the potential for

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[214] Q408
[215] AR 65
[216] Q417
[217] Q418–20
[218] Q430
[219] Q422
[220] Ev, p 190
[221] ibid
[222] ibid
[223] Q409

emission control is small".[224] Furthermore it is argued that low NO_x burners would be seriously detrimental to product quality and while some modern cement making processes can achieve a lower than average NO_x production their application is unlikely to become universal.

(b) *Indirect costs*

(i) electricity prices: 1½ per cent–5 per cent

167. The major indirect cost of introducing emission controls would be that borne by consumers who would face extra charges for electricity usage. If the CEGB were to retrofit 12 power stations the cost of electricity generation at those sites would rise by 9–10 per cent[225]. Over the whole electricity network, total generating costs would rise by 5–6 per cent.[226] This cost would be heaviest at the time when the whole programme is fully implemented, ie 1995. According to the Friends of the Earth, "if it is assumed that the price of electricity to the consumer reflects the costs of production, it can be concluded that the increase in price of delivered electricity due to reducing sulphur emissions will be between 3 and 4 per cent" over the next 10–15 years.[227] This can be compared with a real rise in domestic electricity prices of 4 per cent per annum from 1974–82 and 6 per cent for industrial users. In additional written evidence[228] the CEGB pointed out that the annualised costs of £350 million added to the CEGB total costs of £6,800 million implies a 5.15 per cent rise. For large consumers (ie over 20 million units per annum) the price increase would be about 5 per cent and for others it would be about 4 per cent. Nevertheless this would be the increase only when the programme was fully implemented.

168. A more detailed analysis by N Heighton[229] indicates that the Domestic unrestricted Tariff would be raised by less than the CEGB forecast: an estimated 1.9 per cent increasing to 2.4 per cent in the year 2000. These would be once and for all increases, as opposed to annual rates of increase. The tariff for 50 per cent Lead Factor Large Industrial Consumers, which is representative of a larger number of industrial tariffs, would be raised by an estimated 2.6 per cent increasing to 4.6 per cent in the year 2000, again, less than the CEGB forecast. Such increases would be objected to by the Electricity Consumers Council which pointed out that in real terms electricity now costs 43 per cent more than a decade ago while in the past 5 years there had been 7 separate electricity price increases.[230] Furthermore low-income households, for whom fuel expenditure exceeds 11 per cent of total expenditure, would be particularly affected compared with average households, for whom fuel expenditure is 6.2 per cent of their total outgoings.[231] Nevertheless, the increases expected by Heighton "are comparable with changes which on average are likely to occur every one or two years as a result of increases in fossil fuel prices and other factors unrelated to SO_2 control".[232]

(ii) the cost of controlling motor car emissions

169. Motor vehicles emissions of NO_x should, we have argued, be reduced.

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[224] AR 58
[225] Q51
[226] Q73
[227] Ev, p 42; Q134
[228] Letter from CEGB, 28 June.
[229] AR 65
[230] AR 90 para 2.1
[231] ibid
[232] AR 65, p 3

The costs of catalysts would be some £700 millions from the first year of operation, increasing to £5 billion by year 10, according to the AA.[233] These figures have been disputed by a major manufacturer, Johnson Matthey.[234] Lean burn engines would meet EEC requirements, and the necessary technology will be available in 1986. Their cost will be £50–100 per car, but will lead to an energy saving of up to 15 per cent. Given the reasons we have already set out, we believe at the present time "best practicable means", in economic terms as well as in terms of environmental need and proven technology, favours lean burn engines.

(c) *Conclusions: controls on industry*

170. Whilst there are some differences of view over the cost of meeting the requirements of the Directive, it is beyond dispute that in absolute terms it would be substantial. In relation to total energy costs, this is less so. The rise in cost of electricity and motor cars would be less than 5 per cent and at most £100. In West Germany the imposition of controls has led to new research reducing costs whilst increasing the efficiency of control systems.

171. There are, however, grave difficulties associated with the insistence on controlling all plants over 50MW. It penalises industries reliant upon high combustion temperatures. They cannot use modified burners to reduce NO_x emissions, and the cost of denitrification is, we believe, prohibitive at present. **We recommend that those industries reliant on high combustion temperatures, for example the cement and glass industries, should not have NO_x controls put upon them.**

172. A further factor peculiarly relevant to this country is that if a target of a 60 per cent reduction in SO_2 emissions is to be set, this reduction could be centred upon power stations. This would evenly spread the cost of controls. We have not received any evidence to suggest that small industrial plant should be controlled, as in West Germany. **We therefore recommend that the UK should follow what is known as the "bubble approach": it should, in agreement with its EEC partners, agree an overall level of reduction. Each member country should determine how to achieve that. We recommend that existing, small industrial plant should be excluded from emission controls. All new plants should meet SO_2 emission levels contained in the draft Directive, and all those not reliant upon high combustion temperatures should meet the NO_x levels.**

3 COST BENEFIT ANALYSIS

173. We have set out environmental benefits from reduced emissions. We have set out the most practicable approach to achieving EEC reductions, based on the "bubble" approach. We have identified the costs, principally to the CEGB and thereby to electricity consumers. The key question, then, is how to assess those costs against those benefits.

174. An often used method of assessing the desirability of introducing pollution controls is cost-benefit analysis (CBA). This differs from normal project appraisal, which is only concerned with the direct financial implications of undertaking a scheme. CBA is designed to introduce into the decision-making process both a wider view, whereby external effects or spillovers which do not

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[233] Ev, p 167
[234] AR 1

directly impinge upon the decision-taker are included, and a longer view, whereby the future effects of a course of action are given greater prominence. Consequently compared with the financial appraisal of a project, CBA requires greater information on which to base a judgment about the viability of an investment. Monetary values are placed upon all the costs and benefits considered in a CBA. This often requires surrogate measures where the market mechanism fails to identify price levels. The central question is therefore: Is existing damage, the risk of it worsening, the risk of new damage and our present state of knowledge of all these things sufficient to justify a given level of controls?

175. Environmental Resources Ltd (ERL), in a report to the European Commission[235] calculated the figures for the whole community:

(a) loss of revenue from tourism and sport—£20 million per annum

(b) five per cent loss of German forests plus limited further damage elsewhere—£200 million per annum

(c) loss of crop value—£670 million per annum

(d) building damage—£350–1900 million per annum

(e) costs of drinking water treatment in some areas—£14m.

It would not be accurate simply to apply a percentage of these figures to this country in order to assess the benefit to us of controls. This is because we rank low down in the list of European countries suffering from deposition of pollutants.[236]

176. Another study, by the OECD, assumed that every member country spends 0.05 per cent of its GDP on emission control, and argued that Western Europe could achieve monetary benefits of $860–7600 per annum for an annual cost of $1200 million per annum or $5 per person. This excludes the benefit of increased life expectancy and many other intangibles. The magnitude of the uncertainty about the monetary benefits was largely due to the impossibility of estimating these effects accurately.[237]

177. As N Heighton argued the costs of emission control "should be compared with the economic benefits of abatement; however, any attempt to do so will necessarily be speculative".[238] Such sentiments were echoed by other witnesses. Difficulties arise from two main sources. Firstly, the monetary values placed upon spillover benefits may be based upon unrealistic assumptions. For example, the ERL report cited above assumed that on average 40 per cent of the Community's agricultural and horticultural areas are affected by ozone, SO_2 or NO_x concentrations and that on average a 10 per cent yield loss occurs as a result to winter wheat, barley, grapes and root crops.[239] Secondly, and much more importantly, the benefits of pollution control may be intangible and therefore difficult to measure in monetary terms. For example, Jon Strand of Oslo's Institute of Economics argued that "the damage involved is . . . to a large extent intangible, and its measurement should thus be based on individuals' subjective evaluation of the harm done".[240]

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[235] AR 63

[236] 12th out of 27 in terms of kilograms per hectare; Ev, p 64

[237] OECD report, pp 133–4

[238] AR 65

[239] ERL, p 128

[240] Evidence not reported

178. Environmental effects are too often unquantifiable or of no economic value. What price is put on the ability of Norwegians to fish where ancestors had? What is the value of the survival of dippers in Galloway? What is the value of the variety of snails in lakes or lichen diversity? What price visibility? What price would people put on the further disappearance of sphagnum moss from the Pennines? Similar points on various types of wildlife, including natterjack toads, were put to us by the Royal Society for Nature Conservation and Friends of the Earth.[241] These phenomena are all of little to no economic benefit and yet damage to them may be irreversible.

179. Clearly the estimation of economic benefits due to reductions in emissions is difficult to ascertain and can be misinterpreted. Benefits depend upon the level of damage that can be attributed to acid deposition. We believe that while such studies may give an indication of the likely costs and benefits of pollution control, they are likely to underestimate the total cost of damage to the environment because of intangibles and difficulties in quantifying economic values.

180. We believe that there is an environmental problem. Any form of pollution is, in principle, undesirable. While the natural environment does seem capable of absorbing some pollution, it is beyond dispute that SO_2 and NO_x emissions have many deleterious effects, as the Minister agreed when he appeared before us.[242] We recognise, however, that this does not mean controls are desirable at any price. We agree with the Minister that benefits should be commensurate with costs.[243] However, many of those benefits cannot be financially quantified. There are substantial risks of damage to our natural environment and to our buildings. Much of this cannot fit into a cost-benefit analysis. This view is supported by the NERC: "the issue really depends on what emphases the population place upon their environment".[244] The controls we proposed would lead to an additional cost in electricity prices of no more than 6 per cent spread over the next 10 years and an increase of £50–100 in motor cars. These are but small prices to pay for the environmental benefits that would result and the extent to which the vulnerable parts of our own natural environment would be safeguarded.

4 ENERGY CONSERVATION

181. So far we have considered how pollutants may be reduced or eliminated from the emissions caused by burning fossil fuels. Even more important is the need to consider how the total volume of emissions may be reduced. Prevention is always better than cure. It is obvious that any reduction in the demand for energy will lessen the need to burn fossil fuels and consequently the total emissions needed to be treated in one way or another. Hence all practical means of energy conservation are of prime importance.

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[241] 241 AR 10, Ev, p 38

[242] Q672

[243] Q664

[244] Q540

182. Friends of the Earth gave us evidence that "there is an abundant range of conservation technologies which can be applied to almost any kind of energy use . . .'[245] The Energy Committee has reported to the House on energy conservation in buildings.[246] Our evidence on the pollution caused by power stations, in our view, adds weight to the economic and strategic arguments for energy conservation.

183. The Energy Committee, in its Third Report of Session 1982–83,[247] published in April 1983, concluded that there was a strong economic case for proceeding with a greatly expanded programme of Combined Heat and Power (both in the form of industrial co-generation and district heating). It was in the latter area where the Committee felt that more positive Government action was particularly required to stimulate progress. The Committee therefore recommended that steps be taken to put in hand appropriate "Lead City" schemes for district heating, as originally proposed in 1979 by a Committee of Enquiry chaired by Sir Walter Marshall, now chairman of the CEGB. In what they regarded as a crucial passage of their Report, the Energy Committee went on to recommend: **"In order that CHP/DH should not be placed at a disadvantage, ways should be found by the Government to arrange, assess and finance it on the same terms as the other public supply industries. We consider this matter to be urgent."** We endorse this recommendation and its validity was confirmed to us when we visited a coal district heating station in Sweden.

184. The Government's Reply,[248] published in April 1984, did not, in the view of the Energy Committee, address directly the detailed economic arguments in favour of CHP which formed a major part of the Energy Committee's Report. The reply announced that the Government would be willing to provide up to £250,000 for the preparation of each of three local prospectuses for Lead City schemes "on condition that there is a substantial private sector participation in the consortia and on the assumption that further development of CHP/District Heating would be a viable private sector investment". In its initial reaction, the Energy Committee remarked: ". . . the Government's response falls some way short of matching the scope and thrust of our original Report."[249] The Committee announced that it would be seeking the views of interested parties on the Government's response.

185. The value of such programmes, as we saw in Sweden, is two-fold: the more efficient and economic use of energy, coupled with the reduction of pollution. We strongly support the emphasis given to combined heat and power and district heating by the Energy Committee, and **recommend that in any review of the desirability of CPH/DH, full account should also be taken of the pollution aspects highlighted by our Report.**

186. Other means of energy conservation are available and require encouragement. Under the Clean Air Act 1956, central and local government bore part of the cost of converting such burning appliances for use with smokeless fuel. The results have been dramatic. Similar incentives are required in order to attain

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[245] Q140
[246] HC401 (1981–82)
[247] HC314 (1982–83)
[248] HC416 (1983–84), Appendix
[249] ibid, paragraph 2

maximum energy conservation. In this we do not exclude assistance also in the development of pressurised fluid bed combustion technology and lean burn engines for motor cars both of which will lead to energy saving.

V. CONCLUSIONS

187. Several witnesses, including the CEGB and the CBI, have argued that insufficient is known about acid rain to justify decisions for the introduction of emissions controls being taken now. The CEGB is investing substantial sums in environmental research—over £1 million a year—and is contributing with the NCB to the Royal Society's Scandinavian research programme. Sir Walter Marshall, Chairman of the CEGB, drew our attention to how badly-based research was, in his view.[250] Whilst not wishing to postpone action indefinitely, he wanted to be sure 'what the scientific facts are.... If we discover that we must move and we must do something, we will be able to get on with it.'[251] The risk was that "we might spend a lot of money and then find that the effect is negligible.... We are not procrastinating because of the lack of knowledge of the scientific subject. If we had wanted to procrastinate we would not have asked the Royal Society to mount that exercise. We are just trying to do our conscientious job as we see it."[252]

188. The CBI expressed similar concern: "we must have a reasonably well established linkage between the cost and the effect.... the situation is that the linkage is getting more and more blurred.... We should not rush down this track merely because of the rather strident publicity which we are subjected to."[253] It argued there was, in the area of water damage, no genuine time—scale pressure.[254] Lastly, it argued that those seeking for controls were not those who would have to foot the bill.[255]

189. The Government must, of course, take full account of these scientific questions in coming to its conclusions. We welcome the commitment of the CEGB to act if evidence justifies a range of actions. Throughout our Report we have sought to show the extent of evidence in separate areas for the value of reducing emissions. This is not, as the CBI suggested, a media issue run by pressure groups.[256] That sufficient evidence exists to act now is the view of the Governments of West Germany, Sweden, Norway, Canada, the Netherlands, France and many other countries. It is the view of most scientists in West Germany, Sweden and Norway. It is the view, in this country, of the Natural Environment Research Council. We have taken fully into account reservations which have been expressed to us, but we do not feel these outweigh the weight of evidence which we have received. We believe our work demonstrates that sufficient evidence exists to show that the decision to reduce emissions of SO_2, NO_x and hydrocarbons should be taken now.

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[250] Q7
[251] Q22
[252] Q87–8
[253] Q439
[254] Q440
[255] ibid
[256] ibid

190. Our inquiry has left us deeply disturbed over the United Kingdom's current policy position on acid rain. This policy appears to be that the case for controls is "not proven" and that controls which have been approved are "not cost-effective".

191. As our inquiry has progressed the stance of the United Kingdom has become increasingly isolated by its refusal to legislate to reduce SO_2 and NO_x emissions. Since our work began three West European countries have joined those already in the 30 per cent club, and several Eastern European countries have committed themselves to reduce transfrontier emissions by 30 per cent.[257] SO_2 emissions in the United Kingdom have indeed fallen by 37 per cent since 1970, but the levels of high-stack emissions which affect remote areas have not fallen. In 1970, when the 37 per cent fall began, we were the largest emitter in Western Europe. In 1984, we are still the largest emitter. NO_x emissions have not fallen. In Western Europe only West Germany deposits more SO_2 in other countries than does the United Kingdom, and further significant reductions cannot be achieved by either without controls.

192. Some scientists in this country have fought shy of committing themselves to firm conclusions on control options. They consider that these are matters for Government. However, we have derived great value from discussing the problems with them informally in the field, where we have found that they expressed themselves much more freely. Manufacturing and energy-producing industry have used the reticence or uncertainty of scientists to push to the full their case for not embarking on large expenditure on emissions control. Ministers, due to other pressures, have been unable to visit affected areas at risk here and abroad, or to discuss the problem with scientists as we have. They are therefore at a disadvantage which not even the high quality advice available from DOE's Chief Scientist and his staff can make good. We are certain that had they had these other discussions and visits, their conclusions would have been entirely different.

193. Our work, in discussion with independent scientists in this country and abroad, in public and in private, has shown a massive degree of support for controls. Uncertainty over the mechanisms of damage persists, but in all hypotheses the culprits, ultimately, are SO_2, NO_x and hydrocarbons. Evidence exists that reduced depositions will alleviate damage. Further evidence proves that a reduction in emissions will lead to a reduction in depositions.

194. Policy-makers have then to evaluate the cost element. This is not just a matter of cost benefit: many environmental benefits are unquantifiable. It is a matter of the cheapest possible methods of control, and whether a given price is reasonable to achieve benefits. Once imposed, control costs will fall as serious research into control methods begins. We firmly believe that the Government's present position pays too little heed to the weight of scientific consensus in Britain and in Europe that SO_2, NO_x and hydrocarbons emissions are separately and in conjunction destructive to any natural and built environments. That position is accelerating the destruction of our cathedrals. It is destroying fish life. It is placing many of our most outstandingly beautiful areas at quite unacceptable risk. Controls must be introduced as soon as possible.

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[257] At the Munich Conference in June 1984

195. International agreement on emission controls is essential. The United Kingdom should be party to such agreement. However, **we recommend that within whatever national levels are agreed each Government should be free to decide how to achieve the necessary reduction.**

196. For the United Kingdom, the quickest way to reduce SO_2 emissions is by retrofitting power stations: the technology, whilst costly and difficult, is available. **We recommend**

(a) that the United Kingdom join the 30 per cent club immediately, and that this target be achieved by the CEGB being required to reduce its emissions accordingly;

(b) that in the medium-term as power stations come to be refitted the CEGB should be required to instal equipment to attain the overall national reduction of 60 per cent in accordance with the EEC draft directive, that is, by the end of 1995.

This would enable the targets to be achieved without imposing controls on existing other industry. This is, we believe, consistent with "the best practicable means" approach, as the Minister recognised.[258]

197. **Insofar as industry is concerned, we are aware that for some the high costs of meeting control standards may render them uncompetitive, and for others, even if cost is not of major consideration, it would be impractical to install control technology. Accordingly, we recommend that**

(1) EC emission controls levels for SO_2 should apply to all new industrial plant over 50MW from 1.1.89;

(2) For all existing plants the stringent application of "best practicable means" by the Air Pollution Inspectorate should continue;

(3) The Government should give assistance to industry to convert existing plant to meet SO_2 control standards.

198. **Turning to NO_x, we recommend, again consistent with "best practicable means" that all power stations should have low NO_x burners installed during routine shutdowns. With the exception of those industries totally dependent on high combustion temperatures, which we feel should continue to explore other means of reducing their NO_x emissions, we recommend that all industrial users be required to fit low NO_x burners. As before, we recommend that Government give assistance to industry to install low NO_x burners in *existing* plants. We recommend that new motor vehicles be required to have reduced NO_x emissions levels of 40 per cent by 1.1.87, and that the Department of Transport should inquire into the best possible means of reducing emissions from existing motor vehicles.**

199. As we have said, many scientific uncertainties remain. Further research may well suggest other forms of control to provide a more complete response to the problem of acid rain. It may suggest that additional levels of controls on smaller plant may be necessary. It may also demonstrate that additional

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[258] Q682; We have kept the Energy Committee informed about our conclusions on this subject. Since they have not been party to the evidence they do not think it appropriate to express their own view nor, as far as the strictly environmental case if concerned, would they feel competent to do so. We understand, however, that they may wish to examine in more detail the implications for the cost of electricity of sulphur emission controls on power stations, as part of a forthcoming general enquiry into the prospects for electricity and gas prices.

weight must, in certain environments, be given to factors such as land management or forestry practices in order to address fully the effects of acid rain. **We strongly recommend that the Government make a long-term commitment to further air pollution research, with additional funding, channelled through the NERC.**

200. We have also emphasised in our Report the need for more research to improve technology to reduce emissions. High levels of reductions can be achieved for SO_2. **We recommend that the Government encourage the development of research to reduce further the levels of NO_x emissions.** In order to assess more accurately the effect of individual pollution sources, **we recommend that the Government require the emitters of SO_2 and NO_x, from plants over 50MW, to monitor their emissions sources .**

201. A more fundamental strategy is also needed, based upon energy conservation and the more efficient transmission of energy. Combined heat and power and district heating are crucial components in this. It is essential that energy conservation be encouraged by Government incentives and that the Government and the CEGB promote CHP/DH far more positively than either has to date.

SUMMARY OF RECOMMENDATIONS

1 We recommend that BRE be commissioned to conduct detailed research into the effects of acid rain on different types of stone and concrete in a variety of environments. (para 18)

2 We welcome the commitment of PSA's Chief Executive to conduct a short survey of acid rain damage. We recommend that suitable cases should as a matter of course be referred to BRE, and that PSA use a selection of buildings in different materials to monitor any damage additional to natural weathering. (para 23)

3 We recommend that a substantial research programme on the effect on buildings of low-level emissions be initiated. (para 36)

4 We recommend that the Government give urgent and immediate consideration to the cost benefit of preventing the avoidable erosion of both historic and modern buildings. (para 37)

5 We recommend that the Forestry Commission, using its own and West German experts, conduct a survey on the same lines as that in Sweden forthwith. (para 92)

6 We recommend that the Forestry Commission undertake detailed NO_x and ozone monitoring and begin research into acid rain and trees. (para 93)

7 We recommend that the Government commission research on the effects of acid rain on materials, and on means of protecting them, as a matter of urgency. (para 113)

8 We recommend that research on visibility degradation be commissioned. (para 117)

9 We recommend that the Government should commission research in this country on all aspects of risk to human health to which US, Swedish and German research has drawn attention, with a view to establishing whether similar risks exist in this country. (para 124)

10 We recommend that a rural network of monitoring stations at different altitudes over the whole country be set up. (para 134)

11 We recommend that greater impetus be given to the perfection of PFBC technology for commercial use. (para 141)

12 We recommend that the necessary resources be devoted to FGD by the CEGB, not least in order to reduce its cost. (para 145)

13 We recommend that any programme to limit NO_x and hydrocarbons emissions from motor vehicles should be based on lean-burn technology. (para 154)

14 We recommend that those industries reliant on high combustion temperatures, for example the cement and glass industries, should not have NO_x controls put upon them. (para 171)

15 We recommend that the UK should follow what is known as the "bubble" approach: it should, with its EEC partners, agree an overall level of reduction. Each member country should determine how to achieve that. We recommend that existing, small industrial plant should be excluded from emission controls. All new plants should meet SO_2 emission levels contained in the draft Directive, and all those not reliant upon high combustion temperatures should meet the NO_x levels. (para 172, 197)

16 We recommend that in any review of the desirability of combined heat and power/district heating, full account should also be taken of the pollution aspects highlighted by our Report. (para 185)

17 We recommend that the UK join the "Thirty per cent" club immediately; and that the CEGB should be required to reduce its SO_2 emissions accordingly, with the aim of attaining a 60 per cent reduction by 1995. (para 196)

18 We recommend that the Government make a long-term commitment to air pollution research. (para 199)

19 We recommend that the Government require the emitters of SO_2 and NO_x from plants over 50MW to monitor their emissions sources. (para 200)

PROCEEDINGS OF THE COMMITTEE RELATING TO THE REPORT

MONDAY 30 JULY 1984

Members present:

Sir Hugh Rossi, in the Chair

Mr Richard Alexander	Mr Robert B Jones
Mr David Alton	Mr Norman Miscampbell
Mr Sidney Chapman	Mr Allan Roberts
Mr Julian Critchley	Mr Chris Smith
Mr Reg Freeson	Mr John Mark Taylor

The Committee deliberated.

Draft Report on Acid Rain, proposed by the Chairman, brought up and read.

Ordered, That the Chairman's draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 197 read and agreed to.

Paragraph 198 read, as follows:

198. Turning to NO_x, we recommend, again consistent with "best practicable means" that all power stations should have low NO_x burners installed during routine shutdowns. With the exception of those industries totally dependent on high combustion temperatures, which we feel should continue to explore other means of reducing their NO_x emissions, we recommend that all industrial users be required to fit low NO_x burners. As before, we recommend that Government give assistance to industry to install low NO_x burners in *existing* plants. We recommend that new motor vehicles be required to have reduced NO_x emissions levels of 40 per cent by 1.1.87, and that the Department of Transport should inquire into the best possible means of reducing emissions from existing motor vehicles.

Amendment proposed, in line 9, after the word 'means' to insert the words 'including financial incentives'—(*Mr David Alton.*)

Question put, That the Amendment be made.

The Committee divided.

Ayes 3	Noes 6
Mr David Alton	Mr Richard Alexander
Mr Reg Freeson	Mr Sidney Chapman
Mr Chris Smith	Mr Julian Critchley
	Mr Robert B. Jones
	Mr Norman Miscampbell
	Mr John Mark Taylor

Paragraph agreed to.

Paragraphs 199 to 201 read and agreed to.

Resolved, That the Report, as amended, be the Fourth Report to the Committee to the House.

Ordered, That the Chairman do make the Report to the House.

Several papers were ordered to be appended to the Minutes of Evidence.

Ordered, That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House.

Ordered, That the provisions of Standing Order No 92 (Select Committees (Reports)) be applied to the Report.

The Committee deliberated.

[Adjourned to a date and time to be fixed by the Chairman.

Printed in the UK for Her Majesty's Stationery Office
Dd. 900866 1/85 C5